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13. ABSTRACT *(Maximum 200 words)*

THIS INTERIM RESPONSE ACTION ASSESSMENT ADDRESSES A CONTAINMENT, TREATMENT, AND RECHARGE SYSTEM NORTH OF BASIN F FOR CONTAMINANTS THAT ARE ASSUMED TO BE MIGRATING FROM BENEATH BASIN F. ALTERNATIVES FOR EXTRACTION, TREATMENT, AND RECHARGE ARE REVIEWED BASED ON 1) TECHNICAL FEASIBILITY, 2) TIME TO IMPLEMENT, AND 3) COST IN ORDER TO SELECT THE MOST APPROPRIATE TECHNOLOGIES TO MEET THE OBJECTIVES OF THE IRA.

SECTIONS OF THE REPORT DISCUSS THE FOLLOWING:

1. OBJECTIVES AND ASSESSMENT CRITERIA FOR THE IRA
2. HYDROLOGY AND GROUND WATER QUALITY NORTH OF BASIN F
3. HYDROGEOLOGIC AND TREATMENT ALTERNATIVES FOR INTERCEPTING, TREATING, AND RECHARGING THE CONTAMINATED GROUND WATER
4. THE PREFERRED TECHNOLOGY
5. ADDITIONAL INFORMATION NEEDED TO REFINE THE CONCEPTUAL DESIGN
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GROUNDWATER INTERCEPT AND

TREATMENT SYSTEM

NORTH OF BASIN F

INTERIM RESPONSE ACTION

ALTERNATIVES ASSESSMENT

VERSION 3.1

JULY 1988

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1.0 INTRODUCTION

Rocky Mountain Arsenal (RMA) has been the site for manufacture of military surety agents by the Army since 1942 and of pesticides and herbicides by private industry since 1946. Industrial wastes generated from both Army and lessee activities were routinely discharged into several unlined evaporation basins located on RMA. This practice continued until 1956 when Basin F was constructed with an asphalt liner. Discharge of wastes into evaporation ponds resulted in the infiltration and migration of contaminants into alluvial materials and, in particular, the contamination of portions of the shallow alluvial aquifer (USAEWES, 1985).

To prevent off-post contaminant migration, three groundwater treatment systems have been constructed on the north and northwest boundaries of RMA property. Removal of organics at those treatment systems has been accomplished with granular activated carbon. No inorganic treatment has been performed (COE, 1987a).

One of the Interim Response Actions (IRA) required as part of the proposed Consent Decree is the "assessment and selection of a groundwater intercept and treatment system north of Basin F and implementation of such a system as necessary" (paragraph 9.1 (c), Consent Decree, 1988). This IRA project addresses a containment, treatment, and recharge system north of Basin F for contaminants that are assumed to be migrating from beneath Basin F. It is complimentary to the on-going Basin F Liquids, Sludges, and Soils IRA that is also being conducted under the RMA IRA process and consists of remediation of contaminated liquids, sludges, and soils from Basin F.

Extraction, treatment, and recharge alternatives have been reviewed for a system north of Basin F based on technical feasibility, time to implement, and cost in order to select the most appropriate technologies to meet the objectives of the IRA. Preliminary sizing and costing of the preferred assessment alternative(s) have also been performed.

Sections 2.0 and 3.0 of this assessment review the objectives and assessment criteria for the IRA. Section 4.0 reviews the hydrology and groundwater quality north of Basin F. Section 5.0 reviews hydrogeologic and treatment alternatives for intercepting, treating, and recharging the contaminated groundwater. Section 6.0 compares the various hydrogeologic and treatment alternatives. Section 7.0 describes the preferred alternative including preliminary sizing and costing. Section 8.0 identifies additional information needed to refine the conceptual design. Section 9.0 contains the proposed applicable or relevant and appropriate requirements (ARARs) for this IRA. Appendix A contains a summary of raw water quality data. Appendix B describes treatment alternatives appropriate to inorganic compounds. Responses to comments on the Draft Final Alternatives Assessment and the Draft ARARs are presented in Appendix C and Appendix D, respectively.

2.0 RESPONSE ACTION OBJECTIVES

The purpose of the IRA for the interception and treatment of alluvial groundwater north of Basin F is to prevent the spread via groundwater of contaminants that may be emanating from below Basin F. Benefits derived from this IRA are the initiation of a remediation process for contaminated water in this area and the resulting reduction in contaminant loading on the North Boundary Contaminant/Treatment System.

The specific objectives of the Basin F Groundwater IRA are to:

- Initiate capture of the contaminated alluvial aquifer waters suspected to be emanating north from below Basin F as soon as practicable; and

- Collect operational data on the interception, treatment, and recharge of contaminated groundwater from this area that will aid in the selection and design of a Final Response Action.

3.0 ASSESSMENT CRITERIA

The Consent Decree (1988) stipulates that all IRAs shall:

(1) "to the maximum extent practicable, be consistent with and contribute to the efficient performance of Final Response Actions" (paragraph 9.5);

(2) "evaluate appropriate alternatives" and "select the most cost-effective alternative for attaining the objective of the IRA (paragraph 9.6); and

(3) "to the maximum extent practicable, attain ARARs (applicable or relevant and appropriate requirements)" (paragraph 9.7).

The assessment criteria used to evaluate the various hydrogeologic and treatment alternatives are based on these guidelines.

Selection of the most effective alternative will be based on the following specific criteria: (1) timeliness; (2) effectiveness; (3) demonstrated performance; (4) availability; and (5) cost. The benefit to the Final Remedial Plan from implementing this response action as an IRA is dependent on an early implementation. Therefore, timeliness of implementation is a primary criteria in the screening and selection of alternatives. Contamination present in groundwater immediately north of Basin F does not constitute an imminent threat to the public health or the environment.

ARARs are key criteria in the evaluation of alternatives. The establishment of ARARs for the Groundwater Intercept and Treatment System north of Basin F IRA, to be completed as part of the total remedial action conducted at RMA under CERCLA 42 USC 9601 ET.SEQ., will identify legal standards for this IRA that are either specifically applicable or relevant and appropriate to the chemicals or procedures of concern. These ARARs are legal standards to be met to the maximum extent practicable by the IRA. ARARs are discussed in Section 9.0.

3.1 HYDROGEOLOGIC SYSTEM ASSESSMENT CRITERIA

The assessment of the hydrogeologic system alternatives is based on: (1) the aquifer characteristic data as reported by Vispi (1978) and historical drill logs available at the Rocky Mountain Arsenal Resource Information Center from the area north of Basin F; (2) the feasibility of installing and operating a system under the conditions at Basin F; and (3) the system's ability to mitigate contaminant migration. This system will be operated until implementation of the final remedy and will have a lifetime of at least five years.

3.2 TREATMENT SYSTEM ASSESSMENT CRITERIA

The assessment of alternatives for the treatment of groundwater north of Basin F is based on: (1) an influent containing organic and inorganic contaminants as established from available data; (2) the feasibility of available technologies for treating contaminants of concern in a timely and cost-effective manner; and (3) effluent concentrations as low as practicable for a given technology. This treatment system will be operated until the final remedy is implemented and its lifetime is estimated to be a minimum of 5 years.

Evaluation and selection of the most efficient treatment alternative(s) were in part based on the ability of the alternative to reduce contaminant concentrations and migration. Each alternative was also evaluated for its technical feasibility including proven success in treating the contaminants of interest, reliability, availability, complexity, need for pretreatment, ultimate fate of contaminants or production of hazardous sidestreams, need for pilot studies, and flexibility such that the system could readily be expanded to treat varying influent concentrations or flow rates. Alternatives were also compared based on relative capital and operating costs. Preliminary sizing and costing of the preferred alternative(s) have been provided.

4.0 PHYSICAL SETTING

4.1 LOCATION

As stated in the proposed Consent Decree (1988), the IRA consists of assessment, selection, and implementation as necessary of a groundwater

intercept and extraction system located north of Basin F. To most effectively control contaminants moving beneath Basin F, it is best to locate the system as close to Basin F as possible.

Based on the extent of the saturated alluvium, water level data, and drill logs, a location approximately 500 feet (ft) north-northeast of Basin F (Figure 4-1) appears suitable, and this location is used for purposes of this assessment. Other suitable sites may exist.

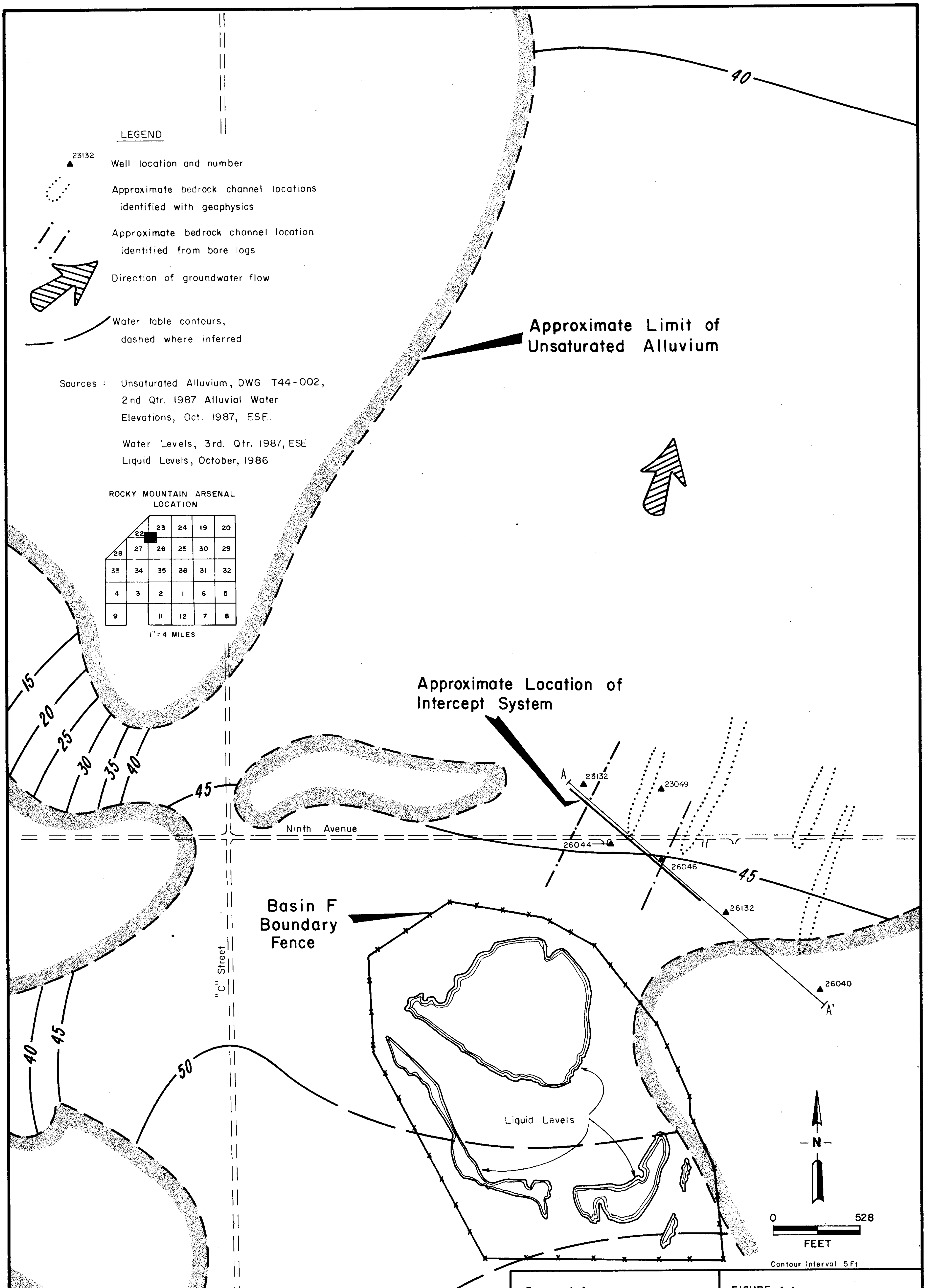
4.2 HYDROGEOLOGY

The regional hydrogeologic conditions at the Rocky Mountain Arsenal have been thoroughly discussed in numerous previous reports (May; 1982, May, 1979) and, therefore, are not discussed in detail here. This report will focus on the area immediately surrounding Basin F and those specific hydrogeologic characteristics that relate directly to a groundwater control system.

In the area of Basin F, the alluvial material is approximately 40 ft thick, predominantly consisting of sand and silt with some gravel and occasional clay lenses (Figure 4-2). It is underlain by the Denver Formation.

The groundwater in the area of Basin F flows predominantly north-northeast to the proposed location for the IRA (Figure 4-1). Several zones, where the underlying Denver Formation is higher than the surface of the water table, appear to impede the alluvial groundwater flow. Therefore, the alluvial groundwater follows the preferential flow pattern shown on Figure 4-1, with gradients that, although low, may vary widely over short distances.

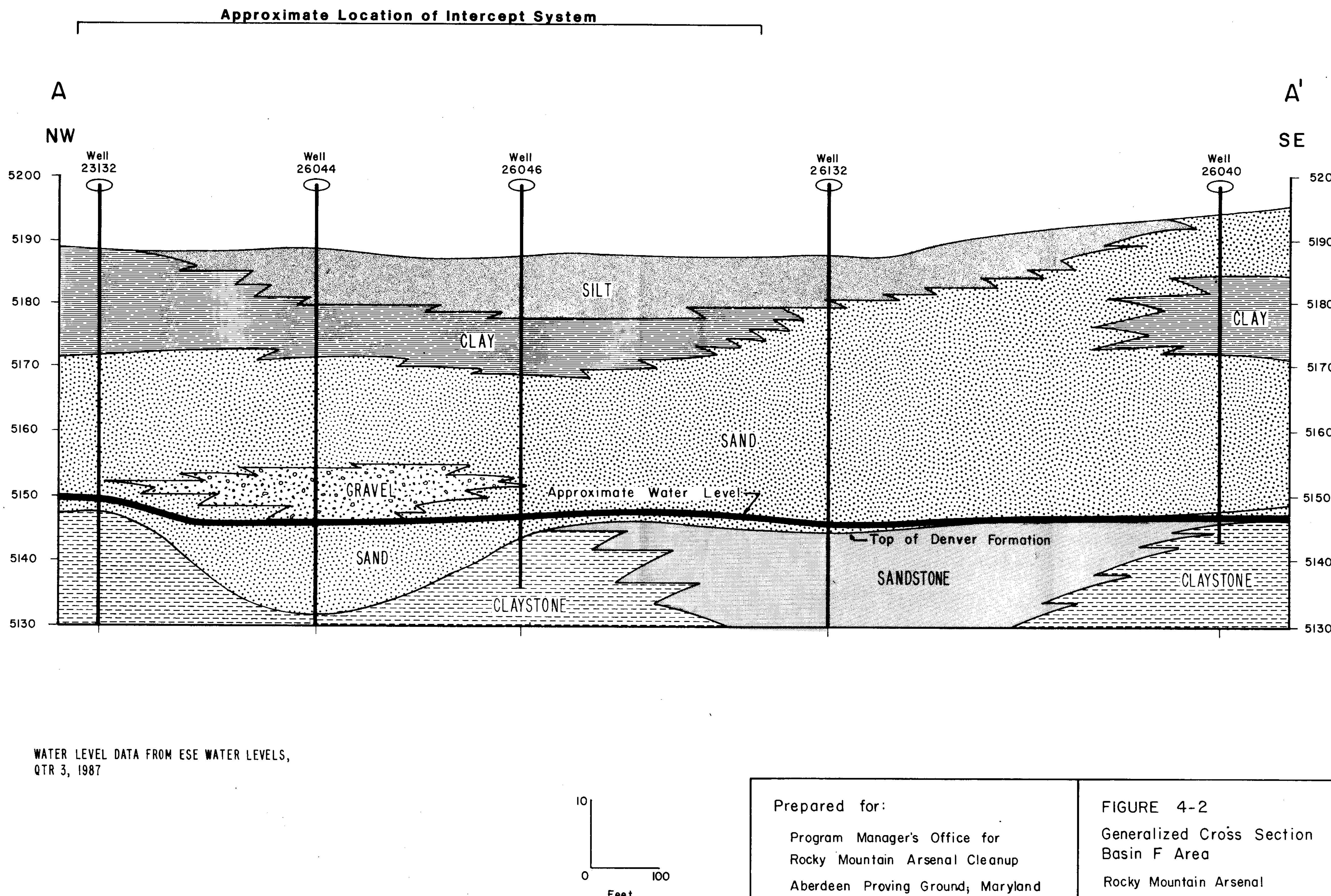
Based on recent water level measurements, the saturated thickness in the alluvial material north of Basin F is about 1 to 2 ft (ESE, 1987). However, in Well 26044, a saturated thickness of 10 ft is seen (Figure 4-2). The screened interval for this well includes Denver claystone and a sand at the base of the alluvium. It is considered representative of the alluvial water levels.



Prepared for:

Program Manager's Office for
Rocky Mountain Arsenal Cleanup
Aberdeen Proving Ground, Maryland

FIGURE 4-1
Generalized Water Table Contours
Basin F Area
Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



WATER LEVEL DATA FROM ESE WATER LEVELS,
QTR 3, 1987

Prepared for:	FIGURE 4-2
Program Manager's Office for Rocky Mountain Arsenal Cleanup Aberdeen Proving Ground, Maryland	Generalized Cross Section Basin F Area Rocky Mountain Arsenal Prepared by: Ebasco Services Incorporated

The surface of the Denver Formation is an ancient erosion surface as evidenced by the numerous paleochannels that still exist in its surface. Well 26044 indicates that the surface of the Denver Formation is topographically lower than in nearby wells, thus indicating the presence of a bedrock channel. A geophysical survey conducted just north of this area (COE, 1987b) indicates the presence of very narrow, shallow channels rather than broad, deep channels as depicted on Figure 4-2. It should be noted that the geophysical survey results have not yet been confirmed by borehole data.

Postulating that a broad deep channel, or even several narrow shallow channels exist north of Basin F, a preferential migratory pathway(s) may exist. These pathways would also provide the most suitable locations for contaminant capture.

In order to design a system to capture migrating contaminants, the hydrogeologic characteristics of the aquifer must be determined. A pump test conducted in Well 23049 (Vispi, 1978) provides these aquifer characteristics locally. The pump test determined the hydraulic conductivity of the alluvium to be 7,000 gallons per day per square foot (gpd/ft^2) or 3.3×10^{-1} centimeters per second (cm/sec).

In many areas of RMA, the underlying Denver Formation is weathered and/or fractured. The hydraulic characteristics of the Denver Formation are unknown at this time and should be determined during the design of the groundwater control system. This is necessary to determine the contributions of these units to the total alluvial groundwater flow.

For the purposes of this assessment, a length of 1,000 ft has been assumed for the extraction system. This length is based on an assumed width for the bedrock channel encountered in Well 26044 (Figure 4-2). A 1,000 ft section will span this channel and overlap into the subcropping Denver sandstone unit to the southeast. Since the hydraulic characteristics of the Denver sandstone are unknown, the effect or need for this overlap cannot be adequately evaluated.

The flow rate in the area affected by the intercept system is variable. As can be determined from Figure 4-1, north of Ninth Avenue a gradient of 0.0011 ft/ft is observed, while south of Ninth Avenue the gradient is 0.0029 ft/ft.

These variations in the gradient indicate a flow rate that ranges from 26 to 70 gallons per minute (gpm). Locally, the flow rate may vary by an even greater amount due to the heterogeneity of the aquifer and variations in the bedrock surface. Estimates of flow rates will vary because of the inherent uncertainties in making these estimates, such as predicting the aquifer heterogeneity and bedrock surface.

The water table in this area has been decreasing in recent years. When Vispi conducted his pump test in 1978, the saturated thickness in Well 23049 was 6.0 ft (Vispi, 1978). In 1987, the saturated thickness in this well was only 2.4 ft (ESE, 1987). As demonstrated by this falling water table, the flow rate has been decreasing with time.

4.3 WATER QUALITY

4.3.1 Projected Water Quality

In order to evaluate the groundwater quality north of Basin F, groundwater data from 48 alluvial wells and 4 Denver wells were reviewed. All data were retrieved from the Army's database on the Tentime System (USATHAMA, 1972-1986). Only data collected since 1980 were used to ensure that recent trends in the groundwater contamination levels were not inordinately skewed by old data. These data are summarized in Appendix A.

All alluvial wells within arbitrary north-south boundaries approximately 1,400 ft north and 1,300 ft south of Ninth Avenue and east-west boundaries approximately 3,900 ft east and 600 ft east, respectively, of "C" Street were reviewed. Both the east and west boundaries used for well selection extend into the zones of unsaturated alluvium. The four Denver wells were selected to determine if contamination were present in the subcropping Denver sand unit. A well location map is presented in Figure 4-3.

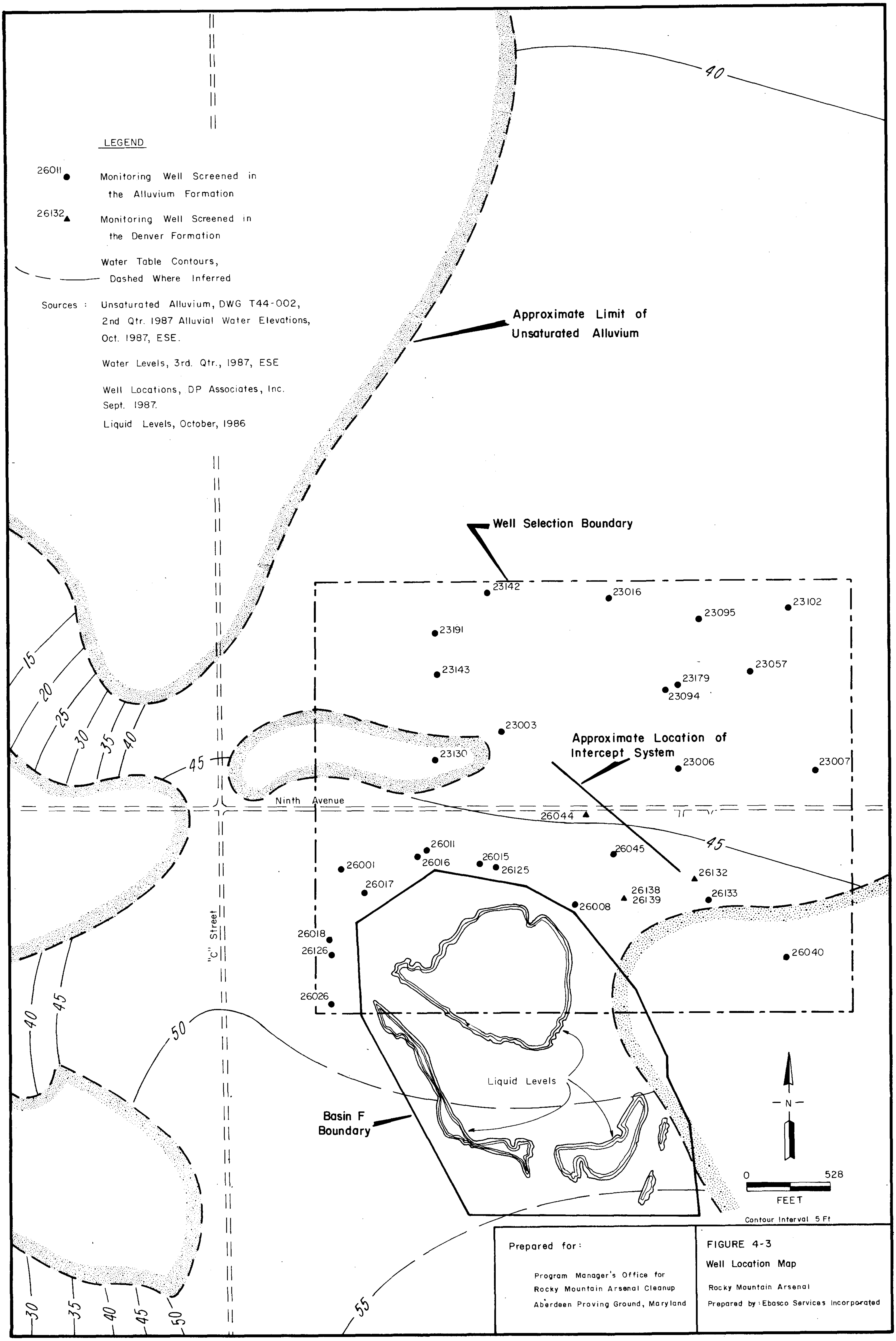


FIGURE 4-3
Well Location Map

Chemical data are available for 29 of the 48 alluvial wells. A total of 101 peaks (or potential analytes) were observed. Of these possible analytes, 68 were identified. Only 57 of the 68 analytes were quantitatively identified as being present at concentrations above their detection limits. Thirty-three of the analytes were identified by retention times only, and this information is included in Appendix A. The wells screened in the Denver Formation did not contain contaminants above their reporting levels and were therefore not further considered. Well 26044 is screened in both the Denver Formation and in the alluvium. Chemical data from this well were therefore excluded from water quality characterization in the Denver Formation.

Range, mean, and median values were generated for each analyte from the data that exceeded the reporting level. Zero values (below reporting levels) were not used in the statistical summary of the data. Inclusion of zero values would skew the mean and median values downward, while exclusion of zero values from the statistical analysis skews the mean and median values upward and provides a more conservative or worst-case estimate of water quality. Exclusion of zero values also eliminates or minimizes the influence of data from plume fringes or data from wells outside the plumes.

4.3.2 Target Analytes for IRA Assessment

Of the 57 chemical analytes reviewed, 22 were selected as target analytes for this assessment based on the frequency of detection and/or concentration levels. Target analytes are defined as selected analytes for the purpose of characterizing representative aquifer contamination for this assessment. Thirteen of the compounds were organics and 9 were inorganic or general water quality parameters. Table 4.3-1 contains a list of the target compounds, the number of hits (number of reported values above the reporting level), the number of analyses, the range of hits, and the projected influent value chosen for that compound. In general, the median value for each analyte was lower than the mean value, indicating that more data points were present toward the lower end of the reported range than toward the upper end. Projected influent values for the assessment were chosen by taking a weighted average of the target compound concentrations in the aquifer and in the recycle from the

Table 4.3-1

Target Analytes for the Alternatives Assessment of Alluvial Groundwater Treatment North of Basin F

Organics	Hits/Samples	Range (ug/l)	Projected Influent Value (1) (ug/l)
Chloroform	50/254	4.4-70,000	6,300
Chlorophenylmethyl sulfide	26/115	1.5-240	44
Chlorophenylmethyl sulfone	78/104	2.6-990	99
Chlorophenylmethyl sulfoxide	25/124	2.9-40	21
Dibromochloropropane	102/300	0.15-51	4.7
1,2-Dichloroethane	13/58	0.83-170	28
Dicyclopentadiene	90/220	2.0-1100	180
Dieldrin	52/104	0.08-8.0	0.93
Diisopropylmethyl phosphonate	232/246	10-4,600	510
Dithiane	81/114	2.0-100	29
Endrin	30/107	0.07-23	1.9
Methylene Chloride	9/56	5.2-200	51
Trichloroethylene	23/61	1.3-69	9.6
Inorganics			
Alkalinity ($CaCO_3$)	89/89	$37,000-12x10^6$	620,000
Arsenic	36/49	3.2-42	14
Chromium	4/26	16-75	39
Fluoride	214/287	1,000-16,000	3,100
Hardness ($CaCO_3$)	140/140	$63,000-6.9x10^6$	$1.4x10^6$
Manganese	21/25	0.033-28,000	6,100
Mercury, Total	4/12	2.4-4.0	3.1
pH(2)	159/159	6.2-8.5	7.3
Sulfates	223/226	$32,000-18x10^6$	960,000

(1) Projected influent values for organic parameters are weighted averages based on 66% untreated influent at mean concentrations and 34% treated recycle at reporting levels. Projected influent values for inorganics are mean concentrations except for pH where the median value is used.
(2) Standard units.

recharge wells. The influent to the treatment system taken from Section 7.1 of this report includes 70 gpm of raw water from the aquifer and 36 gpm recycle of treated water from the recharge wells. Concentrations in the aquifer were assumed to be the mean of the detected concentrations of the target compounds as listed in Appendix B. Concentrations in the recycle stream were assumed to be equal to the effluent from the treatment process, which were taken to be the reporting level for that compound.

Inorganic contaminants are not presently treated in the three RMA boundary groundwater intercept/treatment systems. Moreover, the extent, if any, of control of inorganic compounds in groundwater in the Final Remedial Plan is unknown at this time. Therefore, treatment of inorganic compounds will be considered not within the scope of this IRA. Addition of inorganic treatment can be made later if a benefit is identified in the future. The inorganic profile of groundwater at this site is relevant to this assessment since inorganics can cause scaling or fouling in certain organic treatment processes.

5.0 TECHNOLOGY ALTERNATIVES

5.1 HYDROGEOLOGIC ALTERNATIVES

The various extraction and recharge technologies are discussed separately in this section. Barrier systems are also discussed as they may facilitate the extraction process.

5.1.1 Extraction Methods

There are two basic extraction alternatives available for the Basin F IRA, pumping wells and subsurface drains. A subset to the subsurface drains is an open trench drain. Due to the depth (45 ft) required and the problems of keeping a trench open, secure, and operational for extended periods of time, this method does not appear to be feasible and is not considered in this assessment.

Wells

Groundwater extraction by this alternative is accomplished through a series of pumping wells. The wells are installed in a line approximately perpendicular to the direction of groundwater flow, although other patterns can be utilized

for specific purposes. The pumping system consists of either a vacuum pump or submersible pumps, depending on the depth of the water below ground surface. The pumped water is then collected in a header pipe and transported to the treatment system.

The U. S. Army Corps of Engineers (COE) conducted a feasibility study on the use of pumping wells to contain the groundwater contamination emanating from Basin F (COE, 1987b). Based on the aquifer characteristics determined during a pump test (Vispi, 1978), it appears that a series of alluvial wells would develop a sufficient radius of influence to be considered a viable alternative for this IRA.

Subsurface Drains

Subsurface drains consist of any type of buried conduit that conveys water by gravity flow or pumping. The water is then collected in a sump or, if conditions permit, it may be discharged directly to the surface. Drains affect the water table in much the same way as pumping wells, but they create a continuous zone of depression rather than several overlapping cones of depression.

The advantages of subsurface drains are the lower operation and maintenance (O & M) costs compared to pumping wells and the generally greater effectiveness in capturing contaminated groundwater. However, at the depths required at Basin F, the installation costs for a drain system are generally higher than for wells.

Utilizing the same aquifer characteristics, a subsurface drain could be installed as an interception system to achieve the same goal as the well extraction system. For the Basin F area, a subsurface drain system of the assumed length of 1,000 ft would be installed to a depth of approximately 45 ft.

A disadvantage of the subsurface drain system is dealing with the large volume of potentially contaminated material that may be encountered during construction. It is not possible to assess the volume of contaminated soils

at this time. Soils removed during excavation activities, either at the surface or subsurface, will be returned in the reverse order to the location from which they originated (i.e., last out, first in). Excess excavated soils would have to be checked to determine if they are contaminated or not and then handled accordingly (USEPA, 1985). Any contaminated groundwater encountered during the excavation must be pumped out to allow construction to progress. This contaminated water may have to be sent to another treatment facility or stored until this system's treatment facility is operational.

5.1.2 Recharge Methods

There are four basic methods of recharging the groundwater back into the alluvial aquifer:

- o Recharge wells
- o Subsurface drains
- o Pits
- o Leach fields

These are discussed separately. The recharge method need not be the same as the extraction method.

Recharge wells

Recharge wells inject the treated groundwater into the same aquifer at a rate equal to the extraction rate. The position of the recharge wells relative to the extraction wells should be selected so as to create a beneficial alteration in the groundwater gradient. Usually this means creating a hydraulic "mound" downgradient of the extraction system and enhancing the flow of contaminants toward the extraction system. There may be advantages to recharging remote from the extraction system so that contaminated water can flow to the extraction system from all directions.

At Basin F, a suitable location of the recharge wells would be downgradient of the extraction wells. A "mirror image" configuration of 8 to 10 recharge wells, as suggested by the COE (1987b), would produce the desired effect of reversing the hydraulic gradient between the extraction and recharge system.

This would reduce the flow-through of contaminants. The disadvantage to this procedure is that the water between the extraction and recharge wells is primarily clean, recharged water and would also be collected by the extraction wells. This increases the cost of the overall extraction and the treatment system by diluting the contaminants that are extracted and increasing the flow of water to the treatment system.

Due to the depth of the water table (40 ft) it would not be necessary to pump the water into the recharge wells. The 40 ft of gravity head should be sufficient to recharge the water into the aquifer at a rate equal to the extraction rate. Since pumps would not be required in the recharge wells, the size of the well casing could be reduced.

Subsurface Drains

A subsurface drain could also be constructed to recharge the treated groundwater. A subsurface recharge drain could mirror a subsurface drain used for extraction or operate in conjunction with extraction wells. The construction of the subsurface recharge drain is identical to the construction of the subsurface extraction drain described in Section 5.1.1.

As with the recharge wells, gravity head alone is sufficient to operate the recharge system and recharge pumps would not be required.

Pits and Leach Fields

Pits and leach fields operate on the same principle; the vertical permeability of the soils must be sufficient to allow the treated water to infiltrate at an acceptable rate. In the area of Basin F, the vertical permeability through the alluvium is unknown.

Several specific field conditions must be met in order for pits or leach fields to operate effectively. Conditions that favor the vertical infiltration of water from the surface are:

- o Sandy material with high permeability;

- The absence of low permeability layers that would impede vertical movement; and
- The absence of layers of significantly higher permeability that would encourage lateral migration over vertical infiltration.

In the area of Basin F, the soils are predominantly sandy, but the presence of silt and clay layers would impede the vertical movement of the water. Figure 4-2 clearly shows the presence of two major clay layers. It should be noted that this figure is generalized and does not show small silt and clay layers that would also impede vertical movement.

Gravel layers, such as the one encountered in Well 26044, would also reduce the development of a groundwater mound by laterally dispersing the infiltrating water over a much larger area. The extent to which this lateral dispersion would occur is not known at this time. If the development of a hydraulic barrier is deemed to be advantageous, the use of pits or leach fields would not be recommended.

5.1.3 Barriers

Groundwater control could be enhanced by the use of barriers that stop or impede the flow of groundwater. Barriers are generally either hydraulic or physical. Hydraulic barriers are created by adding or subtracting water to the ambient flow system. Physical barriers are created by changing the permeability of the aquifer by inserting a material with a permeability significantly different from the natural permeability. Both types of barriers serve to alter the groundwater flow pattern to enhance the capture of contaminants.

Hydraulic

For the conditions that exist north of Basin F, a hydraulic barrier is well suited to controlling the migration of contaminants. Hydraulic barriers are created by altering the natural hydraulic flow conditions. The extraction systems described in Section 5.1.1 could create hydraulic barriers.

Likewise, the recharge system would also create or enhance a hydraulic barrier by creating a groundwater mound. The size of the mound would be a reversed mirror image of the trough created by the extraction. Extraction and recharge could be combined to create a more effective hydraulic barrier. Hydraulic barriers have been incorporated into the Northwest and Irondale Boundary Containment Systems.

Physical

Low permeability physical barriers describe a variety of materials that could be installed below ground to reduce or redirect groundwater flow. Slurry walls are the most common subsurface physical barriers because of their effectiveness. The most common slurry wall is built with soil-bentonite slurry. Other types of subsurface barriers (open cut with clay backfill, cement-bentonite, concrete, asphaltic mixtures, etc.) can also be considered, but their generally higher costs are usually not justified unless soil-bentonite is inadequate because of water quality compatibility problems.

If a hydraulic barrier is desired, a physical barrier may be constructed between recharge and extraction systems to limit the recycling of treated water to the extraction system as described by May and Miller (1980). The construction of a slurry wall barrier would require the excavation of a trench approximately 45 ft deep and 1,000 ft long. The barrier wall should be keyed into impermeable claystone units of the Denver Formation. In the area where the Denver sand unit subcrops beneath the alluvium, a slurry wall barrier may not be feasible as the barrier would be in excess of 80 ft deep. A chemical or grout barrier may be used instead, but detailed aquifer characteristics are needed to assess the viability of the option.

The bentonite slurry wall serves the purpose of preventing groundwater flow between the extraction and the recharge system. This has the advantage of eliminating the recirculation of treated water from the recharge system. The only water being extracted through the extraction system is the contaminated groundwater.

Simultaneously, the physical barrier would provide a degree of short-term backup to the hydraulic barrier in the event of a failure (e.g., electrical power outage, etc.). A physical barrier could also reduce construction and operation costs of the treatment portions of the IRA, depending on the amount of water that would otherwise be recycled between the recharge and extraction systems.

A potential negative effect of the physical barrier is in the event of a shutdown of the extraction system. The barrier would then act as a dam for the groundwater flow. Initially, this would not create any problems, but as the groundwater builds up behind the barrier, several undesirable incidents may occur. First, the backed up groundwater would most likely seek release around the ends of the barrier wall, thus widening the contaminant plume. The subsequent pumping required to extract the backed up groundwater could also conceivably exceed the capacity of the treatment system. Lastly, should an alteration of the intercept system be required, such as a variation in the intercept system configuration, the barrier wall could not be easily altered, if at all.

5.2 TREATMENT ALTERNATIVES

A preliminary screening of available technologies has been completed and only those technologies with documented performance and reliability are considered applicable to this IRA.

Treatment technologies can be divided into two groups: those that remove organics and those that remove inorganics. Table 5.2-1 lists treatment technologies under consideration that could be used at RMA and the type of removal each technology is capable of performing. A discussion of treatment technologies appropriate for the removal of organic compounds has been included in this section. Inorganic treatment technologies may be required if scaling or fouling problems occur. Technologies appropriate for removing inorganics are presented in Appendix B. The discussion of each technology addresses such topics as the system operation, required pretreatment, waste streams generated, reliability, design flexibility, complexity, relative cost,

Table 5.2-1 Applicable Treatment Technologies for Contaminated Groundwaters

		Target Compounds	
	Treatment Process	Organics	Inorganics
1.	Air Stripping	X	
2.	Biological Treatment	X	X
3.	Electrodialysis		X
4.	Evaporation	X	X
5.	Filtration		X
6.	Activated Alumina		X
7.	Ion Exchange		X
8.	Carbon Adsorption	X	
9.	Oxidation Process	X	
10.	Precipitation		X
11.	Reverse Osmosis	X	X
12.	Ultrafiltration	X	

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and advantages/disadvantages. Many of the processes have been used or tested on groundwater from RMA, or groundwater containing contaminants similar to those found in RMA groundwater. Performance of these methods is included when appropriate.

Activated Carbon

Activated carbon adsorption is the most widely developed and used technology for treating groundwater contaminated with organics. This is an adsorption process in which the raw water is contacted with activated carbon; the organics in the water adsorb to the surface of the carbon. Adsorption continues until the carbon is saturated. Adsorption is typically conducted in columns.

Adsorption is driven by two factors; the chemical properties of the system (solvent, solute, and carbon) and the physical properties of the carbon. The chemical properties determine the affinity of the solute for the solvent and the affinity of the solute for the activated carbon (Kolmer, 1977). In general, a polar solute will prefer the phase that is more polar, and a nonpolar solute will prefer the phase that is nonpolar. Thus, a nonpolar solute in a polar phase (such as water) will prefer a nonpolar adsorbent (such as carbon). This condition is conducive to efficient adsorption, and the converse condition would result in low adsorption capacities (Kolmer, 1977).

Even more important than the chemical properties of the system are the physical properties of the carbon. In general, high surface area and pore structure of the carbon are the prime factors in adsorption of organics from water; the chemical nature of the carbon surface is of minor importance (CDM, 1986). Generally, activated carbon has been found to remove most organic compounds from water with removal efficiencies ranging from 40 to 99 percent, depending on the contaminant characteristics and physical properties of the carbon. However, activated carbon is marginally effective in removing polar compounds such as methylene chloride (CDM, 1986; S-R, 1983).

When the effluent quality degrades to an unacceptable level, the carbon must be regenerated or replaced. The frequency of regeneration depends on the incoming water quality. The higher the organic content to be removed, the sooner the carbon will be saturated and need to be regenerated. The frequency of regeneration will dramatically influence the capital and operating costs of the system.

Granular activated carbon is used successfully to treat organics at the North Boundary Containment/Treatment System, the Northwest Boundary Containment/Treatment System, and the Irondale Containment/Treatment System on Rocky Mountain Arsenal. Although there have been some reported problems with fine carbon particles from the adsorbers causing plugging problems at the recharge wells, treatment has been satisfactory (PMSO, 1987a; PMSO, 1987b).

The North Boundary System treats higher concentrations of contaminants than the other systems. Dibromochloropropane (DBCP) has been reduced from levels of 6 micrograms per liter (ug/l) to less than the reporting level of 0.2 ug/l. Diisopropylmethyl phosphonate (DIMP) was found as high as 700 ug/l and was generally reduced to less than 50 ug/l. Another contaminant, dicyclopentadiene (DCPD), was reduced from levels of 700 ug/l (and one instance of 1,100 ug/l) to generally less than 10 ug/l. Combined organo-sulfur compounds were found at concentrations of approximately 120 to 150 ug/l in the influent and were below the reporting level in the effluent leaving the plant.

The treatment of contaminated groundwater at RMA using activated carbon has been the focus of various pilot and bench scale testing programs. One program used water from Well 118 (26008) to develop diisopropylmethyl phosphonate and dicyclopentadiene isotherms for 12 commercially available carbons (Thompson & Sweder, 1978). Water from Well 118 was projected to represent groundwater beneath Basin F. Column studies on this water with a variety of carbons determined that a contact time of 40 minutes was required to reduce the diisopropylmethyl phosphonate concentration from 3000-3600 ug/l to 50 ug/l.

Another study developed isotherms for 18 of 25 RMA contaminants tested to determine the carbon capacity required to treat a mixture of contaminants (Walters, undated).

A pilot plant was operated in 1983 to analyze the performance of various treatment technologies on groundwater from the South Plants area (S-R, 1983). Two carbon adsorbers were included in the South Plants Groundwater Treatment Pilot Plant and were used in several tests. The columns were used to treat raw water and water that had been pretreated with an air stripper. It was concluded that, in the presence of very high organic content, granular activated carbon by itself would not be cost effective. When the water was pretreated with the air stripper, scale buildup on the carbon was a problem. During the latter test, the pH of the raw water rose from 6.9 to 8.1, causing a corresponding shift in the Langelier Index from -0.2 to 1.0 and in the Rynzar Index from 7.3 to 6.1. In both cases this indicates a shift from corrosive to scale forming tendencies.

Test results showed breakthrough for chloroform at a carbon loading of about 0.75 pounds (lb) of chloroform per 1,000 lb of activated carbon (750 micrograms per gram (ug/gm)). Breakthrough for dimethyldisulfide (DMDS) was noted at about 0.10 lb of dimethyldisulfide per 1,000 lb of activated carbon (100 ug/gm) and breakthrough for methylene chloride was observed at about 0.02 lb of methylene chloride per 1,000 lb of activated carbon (20 ug/gm). Some leakage of methylisobutyl ketone (MIBK) and pesticides was attributed to nonuniformities in the carbon bed. An empty bed contact time of 30 minutes was maintained throughout the test program. The groundwater treated in these tests contained more organics than the groundwater in the alluvial aquifer north of Basin F.

In general, activated carbon systems are not complex and are easy to operate. Capital and operating costs are moderately high, generally higher than for air stripping. The need to regenerate the carbon is the most costly aspect of carbon adsorption.

Advantages of an activated carbon system are:

- It is well documented and utilized;
- It is simple to operate; and
- It works well on a system containing a mixture of organics.

Disadvantages include:

- The capital and operating costs are moderately high;
- Regeneration is very expensive; and
- If not regenerated, this spent carbon may require disposal as a hazardous waste.

Air Stripping

Air stripping is an effective and proven way to remove volatile organic components from groundwater. It is the process of transferring a contaminant from a liquid phase to a gas phase. In the treatment of groundwater, the raw water is brought into contact with air, and volatile components in the water transfer across the water/air interface into the air. For this to occur, the water must contain the volatile species in excess of equilibrium, and transfer will continue until equilibrium is reached. If the air is continuously replaced with fresh uncontaminated air, and if sufficient contact time is allowed, all of the volatile components will be removed from solution. Nonvolatile organic compounds are not easily removed by air stripping (CDM, 1986).

The tendency for chemical species to transfer from the water to the air phase is often stated in terms of the Henry's Law constant for that specie. Henry's Law states that the concentration of a gas dissolved in a solvent (the amount of contaminant dissolved in the water) is directly proportional to the partial pressure of the gas (contaminant) in contact with the solution (Sienko & Plane, 1974). The proportionality constant, the ratio of vapor concentration to liquid concentration, is the Henry's Law constant. The higher the Henry's Law constant the more easily the compound is stripped (Conway & Ross, 1980). In general, organic compounds can be stripped from water if the dimensionless Henry's Law constant for that compound is above 0.003 (USEPA, 1983).

In general, water entering the air stripper is not pretreated, although filtering may be required if the total suspended solids content is excessive. The waste stream generated by an air stripping unit is the air containing the stripped species. If these compounds are present in low concentrations, the air can be discharged directly to the atmosphere. If air emission standards are exceeded, the exhaust air must be incinerated or run through a vapor phase carbon adsorption unit to remove the contaminants.

The most commonly used, efficient, and economical air stripping system is the packed tower system (CDM, 1986). The tower is packed with material having a very high surface area and void space per unit volume. The water is trickled down the packing while air is passed through the packing by use of a blower. Air:water ratios commonly employed range from 25:1 to 250:1 (Nyer, 1985). Contaminated air is exhausted from the top of the column and treated water is discharged at the bottom of the unit. If the discharged air does not meet air pollution standards, additional treatment can be added to the column. This requirement will add significantly to the capital and operating costs of the facility.

The South Plants groundwater treatment pilot plant included an air stripper that showed removal rates of 96 to 100 percent for volatile organic compounds except methylisobutyl ketone and carbon tetrachloride (S-R, 1983). Tests on this unit also showed that no particular advantage was gained by softening the water prior to treatment and that increasing the air to water ratio increased the removal of all volatile organic compounds.

Air strippers have been used at many sites to effectively remove volatile chlorinated solvents from drinking water supplies (Thibodeaux, 1985). The process is simple to operate and relatively inexpensive to install and run. An air stripper is an appropriate technology for treatment of the volatile organics in the Basin F groundwater. However, this groundwater also contains nonvolatile organic components that would require another method for removal.

Advantages of the air-stripper method are:

- o Moderately low capital and operating costs; and
- o It is simple to operate.

Disadvantages of this method are:

- o Susceptible to freezing (or requires large energy input);
- o Incomplete removal of nonvolatile organics; and
- o Air emission control equipment may be required.

Biological Treatment

Biological treatment removes organic contaminants through microbial assimilation and degradation. Biological systems can also be utilized to remove some inorganics, such as ammonia and nitrate, from groundwater. The most widely used forms of biological treatment are aerobic systems, although anaerobic systems are also very effective. Biological treatment systems may also be classified as either fixed film systems or suspended growth systems, depending on whether the microorganisms are grown on a surface or suspended in the water. Activated sludge systems are the most commonly used aerobic suspended growth systems. Examples of aerobic fixed film systems include trickling filters and rotating biological contactors.

Despite the fact that some wastes (e.g., certain organic compounds and heavy metals) inhibit biological treatment, the biomass can be acclimated, within limits, to tolerate elevated concentrations of the contaminants (USEPA, 1985). Several factors influence performance of this treatment process, such as the concentration of suspended solids, organic load variations, oil and grease, pH, alkalinity, acidity, phenols, sulfides, ammonia, and temperature; thus, some pretreatment may be necessary for effective results. Biological treatment systems can be very effective, are generally easy to operate, and are somewhat self-regulating. The waste side streams consist of excess biomass that is generally nontoxic.

Biological treatment was tested in a pilot study at RMA by the Shell Development Company (Rezai, 1982). Very good results were achieved when the system was operated as an activated sludge system. The major contaminants of concern in this study were chloroform, benzene, and dibromochloropropane. After steady state operation was established, 99.7 percent of the benzene was removed, 91.5 percent of the chloroform was removed, and 96.1 percent of the dibromochloropropane was removed. Daily supplements of ammonium and phosphorus were added to maintain a nutrient-balanced feed.

Groundwater north of Basin F contains chlorinated pesticides that are designed to be persistent in the environment. Biodegradability tests using static-culture shake flasks containing yeast extract and 5 and 10 mg/l of aldrin, dieldrin, and endrin individually found no biodegradation of the pesticides in four consecutive 7-day incubation periods (Tabak et al., 1981). The authors noted that this confirmed other results found in the literature. The U.S. Environmental Protection Agency investigated the treatability of select toxic pollutants and found that biodegradation was not a significant removal mechanism for aldrin, dieldrin, and endrin (USEPA, 1980a). However, at least one study (Matsumura et al., 1978) has indicated that soil microorganisms are capable of biodegrading chlorinated hydrocarbons. Other studies (Bouwer & McCarty, 1984; Bhattacharya & Parkin, 1988; Wilson, 1981) indicate some halogenated organics may degrade more rapidly in anerobic environments than in aerobic environments although often at very slow rates.

Biological systems have low capital and operating costs and are easy to operate. The presence of pesticides in the groundwater from Basin F may limit the effectiveness of biological treatment and would require extensive pilot testing to document effective treatment. Furthermore, the total organic content of Basin F groundwater is too small to sustain a sufficient quantity of biomass needed to make biological treatment feasible (COE, 1987a).

Advantages of biological treatment include:

- o The adaptability of the process to a variety of contaminants;

- The somewhat self-regulating feature;
- Side streams are generally nontoxic; and
- The process has low capital and operating costs.

Disadvantages include:

- The process requires a relatively constant quantity and quality of feed stream;
- The process is subject to upsets and toxicity problems;
- The process may not be effective for all of the organic compounds present; and
- Extensive pilot testing would be required.

<u>Evaporation</u>

Evaporation is a process in which volatile liquids such as water are removed from a waste stream, leaving behind the nonvolatile components. This process is generally used to treat inorganic components and is discussed in more detail in Appendix B. Organic compounds can also be treated with evaporation; however, the highly volatile species will be lost to the atmosphere. Open ponds are commonly used treatment systems in these cases.

Solar evaporation ponds can be quite inexpensive, although if the liquid is considered to be hazardous, a double liner with an intermediate leachate detection system is required (COE, 1987a). A further consideration is the potential requirement to replace the evaporated water for recharge. The vapors could be contained and condensed or make-up water could be purchased from a municipality.

Some advantages of an evaporation system are:

- No liquid waste streams are generated that require further treatment;
- A solar evaporator has low capital and operating costs; and
- A solar evaporator requires no operators.

Some disadvantages are:

- Volatile organics may require expensive emission controls;

- Evaporated water may need to be replaced for recharge to the aquifer; and

- Solar evaporators are dependent on the weather and may take an unacceptably long time to complete the process.

<u>Oxidation</u>

Oxidation refers to the process of destroying organic matter in a contaminated stream by chemical or thermal means. The products of complete hydrocarbon oxidation are water and carbon dioxide.

Thermal methods of oxidation, such as incineration, are generally unsuitable for dilute liquid waste streams due to the large amount of energy required to vaporize the bulk liquid. For dilute liquid streams, chemical oxidation is generally preferred. Three commonly used chemical oxidation processes are: ozonation, hydrogen peroxide, and potassium permanganate. Oxidation is generally not specific to one compound over another and all oxidizable compounds are attacked to varying degrees.

Of the three common oxidizing agents (ozone, hydrogen peroxide, and potassium permanganate) ozone is the most powerful oxidant and can therefore achieve the greatest removal percentages (McShea et al., 1986). However, ozone by itself usually cannot achieve quantitative removal of organics without excessive reaction times or ozone dosages (COE, 1987a).

The presence of ultraviolet (UV) radiation catalyzes the reactions and thereby reduces the reactor volume and chemical requirements. As a general rule, the higher the total organic carbon (TOC), the more oxidant and UV energy required. The actual removal rate for various compounds depends on how easily that compound is oxidized and how readily it absorbs UV radiation (COE, 1987a). The final oxidation products generally do not need to be removed from the treated water; thus, no contaminated waste streams are generated by the process.

Performance can be increased by keeping the UV bulbs free of scaling and by reducing the turbidity of the water (COE, 1987a). Both of these actions will

ensure good transfer of the UV energy to the bulk of the water. Performance can also be enhanced by selecting the appropriate wave length of UV light. Pretreatment can include water softening to reduce scaling problems and filtration to reduce turbidity.

A laboratory bench scale study has been performed to test the efficiency of UV/ozone on groundwater from Well 118 (Khan & Thompson, 1978). Pretreatment to primarily remove iron and manganese was required to avoid interfering with the transmittance of the UV light. The diisopropylmethyl phosphonate concentrations were reduced from influent concentrations of 2,300 to 4,300 ug/l to less than 500 ug/l after contact times of 3 to 4 hours.

The study by COE, (1987a) found references to several successful applications of the UV-ozone oxidation treatment process. Dibromochloropropane was removed to below detectable limits in the treatment of a chemical plant wastewater (Zeff et al., 1983), and PCBs were removed in the secondary effluent of a capacitor manufacturer (Arisman, 1980). Groundwater contaminated with pentachlorophenol and creosote is also being treated successfully (COE, 1987a).

Ozone oxidation with and without the addition of UV energy was investigated for treatment of wastewater generated at the hydrazine blending and storage facility (Ebasco, 1988). The wastewater contained hydrazine, unsymmetrical dimethylhydrazine (UDMH), and monomethylhydrazine (MMH). A further consideration in the oxidation of hydrazine is the production of N-nitrosodimethylamine (NDMA), which occurs as a breakdown product of hydrazine and that also must be destroyed.

Without UV energy, the hydrazine, monomethylhydrazine, and unsymmetrical dimethylhydrazine were destroyed to concentrations below reporting levels of 5 parts per million (ppm), 50 parts per billion (ppb), and 10 ppb, respectively. The N-nitrosodimethylamine that was produced (approximately 150 ppm) was oxidized to less than 2.4 ppb in 20 hours.

Oxidation with the addition of UV energy was also investigated. Research and pilot testing have shown that hydrazine, unsymmetrical dimethylhydrazine, and monomethylhydrazine are rapidly oxidized with this system, and N-nitrosodimethylamine has been oxidized to below a reporting level of 16 parts per trillion (ppt). In addition, miscellaneous byproducts of ozonolysis have been shown to be readily destroyed by UV light.

The South Plants Groundwater Treatment Pilot Plant investigated the efficacy of ultraviolet/hydrogen peroxide (UV/H_2O_2) oxidation on groundwater from South Plants (S-R, 1983). The variables of concern in the tests were the residence time, hydrogen peroxide dosage, and pH. The ultraviolet energy input averaged about 450 watts/gallon of groundwater. The amount of pretreatment was varied and included no pretreatment, air stripping as pretreatment, and air stripping plus the addition of 1 percent pig stomach catalase enzyme. During the tests, it was found that the water heated up considerably due to the UV energy being added. This is something that would have to be addressed if a permanent system were installed.

The results of the test showed that, in general, oxidation was faster at low pH (about 4) than at high pH. Complete oxidation of organics in the feed stream took 2 hours. Higher organic loadings required higher hydrogen peroxide dosages and longer residence times. Addition of a catalyst ($FeSO_4 \cdot 7H_2O$) improved oxidation rates. The final recommended operating conditions were a retention time of 120 minutes and pH of 4. Hydrogen peroxide dosages were recommended at 500 to 1,000 ppm, depending on the total concentration of organics.

Oxidation processes are relatively easy to operate, although the capital and operating costs are high. Additional considerations regarding the UV-ozone treatment process are the possibility of incomplete oxidation of all organic contaminants or of encountering particularly recalcitrant compounds that resist degradation. In addition, both pretreatment and post-treatment may be required to ensure complete removal of contaminants. In any case, pilot testing to determine optimum operating conditions for the incoming water quality would be necessary.

Some advantages of the oxidation processes are:

- o The ability to achieve virtually complete destruction of toxic organics;
- o No waste side streams; and
- o Relative ease of operation.

Disadvantages include:

- o High capital and operating costs;
- o Pretreatment may be necessary; and
- o Oxidation products may require further treatment.

Reverse Osmosis

Reverse osmosis is a membrane separation process that can reduce concentrations of dissolved organic and inorganic compounds and ions by 90 percent or more (Jhawar & Sleigh, 1975). Osmosis is the natural tendency of water to pass through a semi-permeable membrane from the weak solution side to the strong solution side. Pump pressures can be applied to reverse this process and force water from the concentrated side to the pure (permeate) side. The performance of reverse osmosis systems is strongly influenced by the type and configuration of the membranes being used. Pilot testing is often required to determine the best system design for a particular waste stream.

Deterioration of the membranes through chemical attack and fouling and plugging of the flow system may make pretreatment necessary. Pre-filtration to at least 5 microns is generally required, and chloride concentrations above 10,000 mg/l may cause corrosion of the process equipment (COE, 1987a). The side stream produced by this process is about 5 to 30 percent of the feed stream.

Treating organics with reverse osmosis poses different problems than treating inorganics. Organics tend to adsorb to the membrane surface as much as they are rejected into the concentrated stream. Also, membranes can only stop compounds having molecular weights larger than 150 to 200. Dicyclopentadiene

and diisopropylmethyl phosphonate have molecular weights of 128.2 and 180.2, respectively, while aldrin and dieldrin have molecular weights of 364.9 and 380.9, respectively (COE, 1987a). This means that, unless they were adsorbed by the membrane, dicyclopentadiene and diisopropylmethyl phosphonate would partition to the permeate while aldrin and dieldrin would be found in the concentrate. Both streams would then require further treatment for organics. A high total dissolved solids (TDS) content will lead to a large reject stream that would require further treatment (COE, 1987a).

A reverse osmosis system was evaluated for inorganics removal as part of the South Plants pilot plant study (S-R, 1983). It was also determined that the system did remove some, though not all, of the chloroform that had passed through the pretreatment processes.

The primary advantage is:

- o It has the ability to remove organic molecules with a molecular weight greater than 200, inorganics, and metals.

Disadvantages include:

- o The requirement for extensive pretreatment, depending on waste characteristics;
- o A membrane life of 2 to 3 years;
- o High capital costs;
- o The requirement for sophisticated control equipment; and
- o The production of a concentrate stream that would require treatment and disposal.

Ultrafiltration

Ultrafiltration is a form of filtration that is appropriate for removal of some organics. An ultrafilter is a porous membrane that is permeable to some compounds and impermeable to others. In addition to removing very small particulate matter, the process is also applicable for organic molecules generally ranging in size from 500 to 500,000 molecular weight (Weber, 1972). Removal of a substance is related to its molecular shape, size, and flexibility.

Ultrafiltration is similar to reverse osmosis except that much lower feed pressures are used, usually in the range of 5 to 100 pounds per square inch (psi). The process produces a concentrated waste stream that is usually less that 5 percent of the influent volume. As a filtration technique, ultrafiltration is a very expensive due to its large particulate pretreatment requirements and its membrane costs. However, it is a very effective process for removing many large organic molecules. The organic molecules of concern in the Basin F groundwater all have molecular weights less than 500, and would therefore pass through the filter membrane.

Advantages of the ultrafiltration process are:

- It can remove large organic molecules; and
- It operates at a lower pressure than reverse osmosis.

Disadvantages are:

- Small organic molecules are not removed; and
- Capital and operating costs are high.

6.0 <u>SYSTEM ALTERNATIVES</u>

6.1 NO ACTION ALTERNATIVE

Although the No Action Alternative is normally evaluated as part of the alternatives evaluation phase of both interim and final response actions at CERCLA sites, paragraph 9.1 of the proposed Consent Decree (1988) states that the IRA for the system north of Basin F will be implemented as necessary. Determination to proceed with this IRA will be made in the decision document.

6.2 HYDROGEOLOGIC ALTERNATIVES

There are essentially eight hydrogeologic alternatives available for the Interim Response Action at Basin F. These alternatives are based on various combinations of extraction, recharge, and barrier systems. In evaluating the alternatives, it was assumed that all systems would utilize an extraction and a recharge technology. These systems were compared with and without a physical barrier.

6.2.1 Alternatives Screening

Extraction wells and subsurface drains appear to be feasible extraction technologies. Wells operate best in permeable sands and gravels that are likely found in the area, particularly in the suspected channels. Actual well spacings would depend on the location of any channels and on the aquifer permeabilities. Average well spacings of roughly 80 to 100 ft appear to be feasible. Since well spacings and individual pumping rates can be varied to meet site-specific conditions, they can be tailored to fit changing demands.

Additional wells may be added if necessary. If average well spacings of 80 to 100 ft are adequate, an extraction well system would likely be less expensive than installing a subsurface drain to a depth of 45 ft. However, if well spacings must be reduced significantly, a subsurface drain may become the most feasible extraction technology.

If a hydraulic barrier is desired to inhibit the flow-through of contaminated water, the feasible recharge technologies are limited to recharge wells and a recharge trench. If a hydraulic barrier is not desired (so that contaminated water could flow from all directions towards the extraction system), then the recharge system should be located some distance from the extraction system. If no more than 8 to 10 recharge wells are required, then they would likely be more economical than a recharge trench. However, if the required number of recharge wells is much higher, a recharge trench may become cost competitive. In addition to recharge wells and a recharge trench, leach fields may also be acceptable in such circumstances. Depending on the soil permeabilities that will control the infiltration rate, leach fields may be the least costly recharge technology.

If a hydraulic barrier is desired, a physical barrier could be included between the recharge and extraction systems to limit recirculation. The economic benefits reducing the recirculation are not expected to offset the costs of constructing a physical barrier in this location. Consequently, including a physical barrier in groundwater intercept systems is not recommended.

6.2.2 Alternatives Evaluation

As a hydraulic barrier would enhance the effectiveness of a groundwater intercept system, only systems that would produce a hydraulic barrier will be considered for this assessment. Leach fields and pits may not effectively produce hydraulic barriers and have been eliminated from further consideration.

Table 6.2-1 summarizes the remaining systems and their related costs. Estimated costs for a bentonite slurry wall are also included. It should be noted that the costs presented in Table 6.2-1 do not include disposal of contaminated material generated during construction. Of the remaining alternatives, extraction wells and recharge wells would be more cost effective than subsurface drains and would be the technologies of choice.

6.3 TREATMENT ALTERNATIVES

6.3.1 Alternatives Screening

Implementing the chosen treatment process in a timely manner is a major concern. The treatment alternatives will be screened based on the ability to remove organics and the time required to install the process. Inorganic species are of concern only with respect to possible scaling and fouling problems in the process equipment. The need for pretreatment for hardness, manganese, and scaling compounds will be dictated by the ability of the chosen treatment processes to operate with hard water. Possible treatment technologies will be discussed in the same order as they were presented in Section 5.2.

Carbon adsorption is a proven treatment process for removal of organic compounds, although it will not remove polar compounds such as methylene chloride very efficiently. Activated carbon systems are not complex, are easy to operate, require no pilot studies, and could be implemented quickly.

Air stripping is also a well known treatment technology for removal of organics from water. The target contaminants include several compounds with Henry's Law coefficients (Appendix A) that indicate good stripping ability. The list also includes some organic compounds that will not strip easily,

TABLE 6.2-1. HYDROGEOLOGIC SYSTEM COST SUMMARY

Extraction Wells

CAPITAL COSTS	
Drilling	$ 10,000
Installation	45,000
Header & Elec.	148,000
Other Scope Items (20%)	41,000
Design (12%)	29,000
Contingency (15%)	41,000
	$ 314,000
ANNUAL O&M COSTS	15,000

Subsurface Extraction Drain

Excavation	$ 379,000
Drain Installation	29,000
Dewater & Treat Water	50,000
Other Scope Items (20%)	92,000
Design (12%)	66,000
Contingency (15%)	92,000
	$ 708,000
ANNUAL O&M COSTS	$ 11,000

Recharge Wells

CAPITAL COSTS	
Drilling	$ 7,000
Installation	30,000
Header	148,000
Other Scope Items (20%)	37,000
Design (12%)	27,000
Contingency (15%)	37,000
	$ 286,000
ANNUAL O&M COSTS	$ 15,000

Subsurface Recharge Drain

CAPITAL COSTS

Excavation	$ 379,000
Drain Installation	29,000
Dewater & Treat Water	50,000
Other Scope Items (20%)	92,000
Design (12%)	66,000
Contingency (15%)	92,000
	$ 708,000

ANNUAL O&M COSTS $ 5,000

Bentonite Barrier Wall

CAPITAL COSTS

Barrier Wall	$ 250,000
Other Scope Items (20%)	50,000
Design (12%)	36,000
Contingency (15%)	50,000
	$ 386,000

including endrin, chlorophenylmethyl sulfone, and chloromethylphenyl sulfoxide. Inordinately high air:water ratios would be required to remove these compounds. It is therefore apparent that air stripping by itself would not remove all of the components of concern. Air stripping is considered to be less expensive than carbon adsorption.

Biological treatment systems require the total organic carbon concentration to be fairly constant, a condition that is usually met with groundwater. Also, a minimum total organic carbon concentration in the water is needed to sustain the microorganisms. Water quality data indicate that the groundwater north of Basin F is marginally able to provide this level. In addition, not all of the compounds present are readily treatable with biological systems, particularly the pesticides. While treatment of these organics may be feasible, considerable time would be spent in developing and demonstrating an effective biological treatment system. It does not appear that biological treatment would be a viable alternative for this groundwater.

Evaporation is best suited to concentrated streams, such as the side streams generated by other treatment processes, because of the time and energy or size of evaporation units for dilute systems. To treat the entire extracted stream with evaporation would be much too expensive to be done in a mechanical evaporator. A solar evaporator for the same stream would be approximately 70 acres in area and controlled primarily by the weather, not by site personnel. Any water lost to the atmosphere may have to be replaced with purchased water. In light of these considerations, evaporation should be considered as treatment for a contaminated sidestream, but not as a primary treatment technology.

Chemical oxidation is a promising technology but has not been proven on all of the target compounds identified for this project. Extensive pilot testing would be required to determine optimum operating conditions and to verify that target compounds were being destroyed sufficiently. Operating costs and pretreatment requirements cannot be estimated at this point. Because the process is largely unproven for many of the target compounds, this technology would not be recommended for use in the Basin F groundwater treatment system.

Reverse osmosis is a proven technology for removing species with molecular weights down to about 150 to 200. The target compounds include compounds with molecular weights both above and below this range. If reverse osmosis were used on this water stream, some of the target compounds would pass through the membrane and some of them would not, resulting in contaminants in both the effluent and reject streams. In addition, extensive pretreatment would be required, pilot studies would be necessary, and capital and operating costs would be very high. These considerations eliminate reverse osmosis from further consideration.

Ultrafiltration is best used to remove large organic molecules having molecular weights greater than 500. The compounds of concern in this study are smaller than that; therefore, ultrafiltration is not appropriate for this system.

6.3.2. Alternatives Evaluation

Based on the above discussion, air stripping and carbon adsorption are the technologies best able to remove target compounds in the groundwater north of Basin F.

Carbon adsorption is a proven technology at RMA and is capable of removing all of the compounds of concern. The carbon consumption was estimated for the influent chloroform concentration by using carbon adsorption isotherms for chloroform (EPA, 1980b). An adsorber containing 20,000 lbs of carbon would be exhausted every 22 days. The carbon system can be implemented quickly and without the need for pilot plant testing.

Preliminary review of the available data on air stripping indicates that all but three of the organic compounds in Table 4.3-1 can be stripped. The exceptions are chlorophenylmethyl sulfone, chlorophenylmethyl sulfoxide, and endrin. Some of the other compounds, such as diisopropylmethyl phosphonate (DIMP) and dieldrin can be stripped, but not readily. A review of the groundwater data indicates that the system may be required to remove diisopropylmethyl phosphonate at a rate of 99 percent. No data on

experimental conditions for diisopropylmethyl phosphonate were found, although a calculated air:water volume ratio of 1200:1 for 99 percent removal was estimated from solubility and vapor pressure data (CDM, 1986). This ratio is an order of magnitude greater than that usually employed in air strippers.

One possible treatment process would be to utilize both air stripping and carbon adsorption. Air stripping is considered to be more economical than carbon adsorption and would normally come first in the treatment train. This configuration would allow the bulk of the volatile organics to be removed before reaching the adsorbers, thereby reducing loading on the more expensive carbon adsorption system. The air stripper would not be operated at a high air:water ratio and the adsorbers would then remove compounds that are not stripped. A significant increase in the overall adsorption capacity for the remaining organics is to be expected. Based on 99 percent chloroform removal in the air stripper, the regeneration interval for a 20,000 lb carbon bed was estimated to be 88 days by using isotherm data (EPA, 1980b).

However, there is a possibility that the hardness of the water will cause precipitation of calcium, magnesium, and manganese salts on the carbon. This problem can be resolved by pH adjustment of the feed water, or by repiping the system such that the air stripper follows the carbon system. Use of the air stripper after the carbon adsorption system is less desirable but is still an effective system since the first compounds to break through the carbon system will be the volatiles and these will be effectively removed by the air stripper. This arrangement would have the added benefit of reducing the air emissions from the air stripper if this were a problem.

Air stripping is likely to cause scaling in the carbon columns or cause injection problems if used as the last step of the treatment process. If air stripping combined with carbon adsorption is selected, an inorganic treatment step may have to be added to the system. The inorganic treatment may be an expensive system, such as lime softening, or a simple system, such as pH adjustment by acidification. Air stripping will not be considered a feasible alternative if lime softening is needed, because of the complexity and high

capital and operating costs of such a system. A pilot study should therefore be performed to determine the need for treatment of inorganics. Such testing would delay plant start-up. Another delaying factor for the implementation of air stripping is the need to determine air emission requirements. Inclusion of emissions control, such as of a vapor phase treatment system, would increase the capital and operating costs to the point of canceling the economic benefit of the air stripper. It would therefore be desirable to either adjust the removal efficiencies and the design of the air stripper to meet air discharge requirements or to place the air stripper after the carbon adsorber, in which case the discharge problems may be eliminated.

Preliminary estimates of costs associated with a carbon adsorption system and a carbon adsorption with air stripping system are presented in Table 6.3-1. Preliminary estimates for filtration of carbon fines, lime softening of 50 percent of the influent stream, and vapor phase control for the air stripper have also been presented in Table 6.3-1. Costs presented in this table exclude facility costs.

Based on this discussion, it is recommended that a carbon adsorption system be installed first. If emission controls would not be required, an air stripper should also be installed as a test unit and optimum operating conditions could be determined after carbon treatment has begun. In this way a system could be operational relatively quickly, but with the possibility of increasing efficiency if tests with the air stripper show it is effective in spite of very hard water.

A review of water quality data indicates that water hardness may interfere with the efficiency of the system by clogging or scaling the carbon adsorption units and the recharge system. Pretreatment should be considered, and is recommended in the form of pH adjustment by acid addition. This form of pretreatment should reduce scaling with minimal cost increase. If an adjustment does not prove adequate in this application, a costly softening process may be required, potentially producing a voluminous and likely hazardous sidestream.

TABLE 6.3-1 TREATMENT SYSTEM COST SUMMARY*

Alternative 1: Activated Carbon Adsorption

CAPITAL COSTS

Two Adsorption Vessels	$150,000
Carbon	40,000
Influent and Backwash Pumps	8,000
Filter	2,000
Acidification System	5,000
Other Scope Items (20%)	41,000
Design (12%)	30,000
Contingency (15%)	41,000
	$317,000

ANNUAL O&M COSTS

Carbon Regeneration and Replacement	$390,000
Electricity	10,000
Labor	25,000
Chemicals	5,000
Monitoring	75,000
Maintenance	3,000
	$508,000

Alternative 2: Activated Carbon Adsorption and Air Stripping (no emission controls)

CAPITAL COSTS

Two Air Strippers Including Fans and Blowers	$ 28,000
Influent and Effluent Pumps	8,000
Two Adsorption Vessels	150,000
Carbon	40,000
Backwash Pumps	4,000
Acidification System	5,000
Filter	2,000
Other Scope Items (20%)	47,000
Design (12%)	34,000
Contingency (15%)	48,000
	$366,000

TABLE 6.3-1 TREATMENT SYSTEM COST SUMMARY (cont'd)*

ANNUAL O&M COSTS

Carbon Replacement and Regeneration	$104,000
Electricity	16,000
Labor	25,000
Chemicals	5,000
Replacement Packing	5,000
Monitoring	
Air	11,000
Water	75,000
Maintenance	4,000
	$245,000

AUXILIARY COST CONSIDERATIONS

Lime Pretreatment (50 percent of Influent)

CAPITAL COSTS

Storage tank	$ 15,000
Contact basin	20,000
Lime feed system	5,000
Dewatering System (plate and frame press)	20,000
Pumps	2,000
Disposal: initial container	2,000
Laboratory Equipment	2,000
Other Scope Items (20%)	13,000
Design (12%)	9,000
Contingency (15%)	13,000
	$101,000

ANNUAL O&M COSTS

Lime	$693,000
Electricity	12,000
Disposal & Transportation	180,000
Monitoring (Sludge)	5,000
Maintenance	1,000
	$891,000

TABLE 6.3-1 TREATMENT SYSTEM COST SUMMARY (cont'd)*

Vapor Phase Carbon Adsorption

CAPITAL COSTS

Adsorbers	$ 50,000
Other Scope Items (20%)	10,000
Design (12%)	7,000
Contingency (15%)	10,000
	$ 77,000

OPERATING COSTS

Carbon Replacement and Regeneration	$384,000
Electricity	5,000
Labor	8,000
Monitoring	11,000
Maintenance	1,000
	$409,000

* Costs were obtained from the following vendors:
Holloman (1988), Wood (1988), Orsini (1988), Pfister (1988), Evans (1988).

7.0 DESCRIPTION OF SYSTEMS

7.1 HYDROGEOLOGIC SYSTEM

The hydrogeologic system that is recommended consists of an extraction well recharge well system without a physical barrier. This system is comprised of 8 to 10 extraction wells spaced an average of 100 ft apart. A "mirror image" recharge well system will be located approximately 200 ft hydraulically downgradient of the extraction wells. The extraction system will extract the groundwater at a system rate of 110 to 160 gpm based on the COE model (COE, 1987b). An ambient flow across the system of 70 gpm and a recycle flow between the recharge and extraction system of 36 gpm approximates the COE model's prediction.

For the purposes of this assessment, the extraction and recharge well system is the most cost-effective system of those that are considered to be technologically viable for the Basin F IRA.

7.2 TREATMENT SYSTEM

For the purposes of this assessment, to effectively treat the groundwater north of Basin F with simple, proven technology and with minimal delays, a carbon adsorption unit followed by filtration is recommended. The use of air stripping in conjunction with carbon adsorption is a promising technology and may provide substantial reduction in operating costs over carbon adsorption alone. Air stripping has not been included in the preliminary design because of air emission and operational data gaps that must be addressed and would delay implementation of the IRA. Air stripping should be investigated as a complementary process to carbon adsorption.

The following treatment process stream is recommended:

- Pretreatment with acid;
- Two activated carbon adsorption units in series to remove organic contaminants; and
- Filtration of adsorber effluent to remove carbon fines and prevent clogging of recharge wells.

Support units to the treatment process would also be needed. A sump would be required to equalize influent groundwater concentrations and flow. A holding/settling tank would be required for batch treatment of backwash waters. The treatment system should be enclosed to prevent icing problems during winter operations and to permit additional pilot testing, if desired.

The technologies selected have been proven effective and reliable off-site and on RMA with RMA-specific contaminants. The system described should have a lifetime of at least five years and could handle a variable flow stream. The system may be readily expanded to include larger units or alternate technologies in support of or for inclusion in the Final Response Action.

8.0 ADDITIONAL INFORMATION

Refinement of the conceptual design presented in this assessment may require the collection of additional information as described in the following sections. This information may be collected during the predesign phase of the IRA or during the first year of operation.

8.1 HYDROGEOLOGIC SYSTEM

A summary of data needs for the groundwater extraction system includes:

- A site-specific characterization of the hydrogeologic conditions at the system location and their effect on the design parameters;
- A definition of the contaminant plume based on specific chemical concentrations; and
- An evaluation of the potential influence of the Denver sand unit subcropping near Basin F.

The hydrogeologic conditions immediately north of Basin F are not fully characterized at this time. The currently available data allows for a good general understanding of the hydrologic regime, but specific information about the location selected for the intercept system lacks sufficient detail. For example, the locations and depths of the suspected bedrock channels are not known with sufficient accuracy to allow a well to be located in the zone of maximum permeability or saturation. For wells to be effective, this information is essential. If the wells are located in areas of low permeability or low saturation, they will not function properly.

The necessary information can be collected through the installation of judiciously placed wells and/or geophysical investigation. A geophysical survey, "ground truthed" by drilling logs (both existing and new), may be the most cost-effective means of filling in this data gap. A conservative time estimate for completing this type of investigation would be 2 to 3 months.

It is also recommended that the aquifer's hydraulic characteristics be determined at the site of the extraction system. The best method for doing this is by conducting a pump test at the location of the intercept system. These wells could then be incorporated into the extraction system itself. However, it is often difficult to incorporate these wells into the system as smoothly and efficiently as desired. In addition, the cost of the pump test and subsequent disposal of the contaminated groundwater make this a less attractive solution.

A more reasonable approach would be to conduct slug tests at the intercept system location and in the wells used by Vispi (1978) to conduct his pump test. In this way, the slug tests could be calibrated against the more accurate pump test and the information extrapolated to the area of the intercept system with some degree of confidence. This method eliminates the problems associated with a pump test, particularly the disposal of contaminated water.

Drilling of wells in the exact area of the intercept system would also provide physical samples from which grain size and porosity could be determined. The grain size and porosity of the formation would determine the maximum particle size in the treatment plant effluent that could be accepted by the recharge wells without causing significant plugging of the aquifer.

The total hydrogeologic system encompasses the alluvial material and the underlying Denver Formation. Obviously, any flow from Denver sand units that subcrop near the hydrogeologic system need to be taken into account when evaluating the flow in the hydrogeologic system. Potential recharge of the alluvium from the Denver Formation is still uncertain at this time. Aquifer

tests should be conducted in the vicinity of the proposed hydrogeologic system location and in the subcropping Denver sand unit in order to adequately design and optimize the system's operation.

8.2 TREATMENT SYSTEM

The water quality data used for this assessment was collected from wells in the general area of the proposed extraction and recharge system from 1980 to 1987. As noted in Section 4.3, several data values were considered to be anomalous or outliers and were eliminated from the evaluation. To ensure that the data used for the design of the IRA is adequately represented by the design water quality data presented in this report, water samples should be collected from as many alluvial wells upstream and in the immediate vicinity of the proposed extraction system as possible and analyzed for organic and inorganic contaminants and general water quality parameters. This analysis would ensure that temporal and areal variations in the contaminant concentrations have not skewed the design data significantly to prevent identification of all key target contaminants.

Air stripping of the volatile organic contaminants appears to be both a technically and economically desirable treatment process for the IRA. However, several significant design and operational considerations must be evaluated before an air stripping unit can be adequately designed. A key consideration is the need for additional equipment to control the discharge of contaminants to the atmosphere. The requirement for emission control equipment would add significantly to both the capital costs and the operational costs of the process. The emissions from an air stripper may be required to meet chemical- and location-specific ARARs. If chemical-specific ARARs do not exist, an air quality dispersion model may be needed to estimate exposure levels to RMA workers and to neighboring residents. A risk assessment may be needed to evaluate the health risks associated with the estimated exposure levels.

Results from both the South Plants pilot plant study (S-R, 1983) and the Well 118 studies (Khan & Thompson, 1978) indicate that the oxidation and

precipitation of manganese and the precipitation of hardness-related compounds may be caused by an air stripper. This could potentially cause severe scaling and plugging problems with the activated carbon adsorbers similar to that noted in the South Plants pilot plant study. To prevent precipitation of these compounds, acid may be added in the influent to this process. In-plant testing would be required to verify the success of this option and to determine appropriate chemical feed rates.

If the addition of acid is determined to be inadequate to prevent precipitation of these compounds, pilot testing of manganese precipitation and softening processes would be required. The focus of these tests would be to determine the appropriate chemical feed rates, the volume of sludge generated, the concentration of contaminants in the sludge, and the treatability of the sludge by such processes as filtration, centrifugation, and evaporation.

9.0 PROPOSED ARARs FOR BASIN F GROUNDWATER INTERIM RESPONSE ACTION

9.1 ATTAINMENT OF ARARs

The interim action process reported to the Court on June 5, 1987, in United States v. Shell Oil Co. provides that the IRAs (including this IRA to intercept and to treat groundwater north of Basin F) shall, to the maximum extent practicable, attain ARARs. A similar provision appears in Paragraph 9.7 of the proposed Consent Decree.

9.2 IDENTIFICATION AND SELECTION OF ARARs

Paragraph 9.7 of the proposed Consent Decree provides that the Organizations, DOI, and the State shall have an opportunity to participate at the RMA Committee level, in the identification and selection of ARARs that may be applicable to the IRAs. The Army is to present its proposed decision on ARARs to the other Organizations, DOI, and the State prior to, or as part of, the draft IRA Assessment.

In this instance, the Army requested in a January 19, 1988, letter by counsel that EPA, Shell, and the State nominate by February 12, 1988, any ARARs that they believed warranted initial consideration by the Army in connection with this IRA. No responses were received to these letters.

Following receipt of this draft, the Army will hold a meeting of a subcommittee at the RMA Committee level to discuss this draft ARAR document, if this is the desire of any of the Organizations, DOI, or the State. However, the Army needs to receive any such request in writing within seven days of receipt of this document.

9.3 SELECTION OF ARARs AND DETERMINATION OF ARAR IMPACT

9.3.1 Ambient or Chemical-Specific ARARs

Ambient or chemical-specific requirements set health or risk-based concentration limits or ranges in various environmental media for specific hazardous substances, pollutants, or contaminants. Such ARARs either set protective cleanup levels for the chemicals of concern in the designated media or indicate an appropriate level of discharge.

For purposes of this IRA, which is to be conducted solely in the on-post RMA areas where the existing and continuing restructions on groundwater use apply, there are no pertinent chemical-specific ARARs.

9.3.2 Location-Specific ARARs

Location-specific requirements set restrictions on activities depending on the characteristics of the site or the immediate environment. These requirements function like action-specific requirements. Alternative remedial actions may be restricted or precluded depending on the location or characteristics of the site and the requirements that apply to it.

With respect to this interim action, the provisions of 40 C.F.R. paragraph 141.5 (siting requirements for public water systems) are relevant and approprate. The foregoing regulation does not constitute an "applicable" location-specific ARAR in this context. The Basin F intercept and treatment system does not constitute a public water system, no one is drinking or is to drink water to be treated by this system, and this IRA is being conducted pursuant to CERCLA, entirely on-site and in compliance with CERCLA Sections 120 and 121, 42 U.S.C. paragraphs 9620 and 9621. Thus, the regulatory jurisdiction otherwise associated with the Safe Drinking Water Act and the

National Primary Drinking Water Regulations simply do not arise. In these circumstances, the nature of the remedial action is such that the jurisdictional prerequisites of these requirements are not met. Thus, the identified regulation is not applicable here.

Nevertheless, Section 141.5 does address location-specific problems or situations suffficiently similar to those encountered at the RMA CERCLA site that use of this regulation is well-suited to the site and accordingly it will be treated as "relevant and appropriate." A requirement that is "relevant and appropriate" must be complied with to the same degree as if applicable. However, there is more discretion in this determination; it is possible for only part of a requirement to be considered relevant and appropriate; the last being dismissed if judged not to be relevant and appropriate in a given case.

Accordingly, the Basin F intercept and treatment system will be located to conform to the substantive siting provisions of 40 C.F.R. paragraph 141.5 as follows:

(i) The system will not be located where there is a significant risk from earthquakes, floods, fires or other disasters which could cause a breakdown of these improvements; and

(ii) The system will not be located within the floodplain of a 100-year flood.

It should be noted that Paragraphs 23.2 (e) and (f) of the proposed Consent Decree provide that:

(e) Wildlife habitat(s) shall be preserved and managed as necessary to protect endangered species of wildlife to the extent required by the Endangered Species Act, 16 U.S.C. paragraph 1531 et seq., migratory birds to the extent required by the Migratory Bird Treaty Act, 16 U.S.C. paragraph 703 et seq., and bald eagles to the extent required by the Bald Eagle Protection Act, 16 U.S.C. paragraph 668 et seq.

(f) Other than as may be necessary in connection with a Response Action or as necessary to construct or operate a Response Action Structure, there shall be no change permitted in the geophysical characteristics of RMA that has a significant effect on the natural drainage at RMA for floodplain management, recharge of groundwater, operation and maintenance of Response Action Structures, and protection of wildlife habitat(s).

While these provisions are not ARARs, they obviously must be complied with for purposes of this IRA. Based on where the Basin F intercept and treatment system will be located, as well as when and where the IRA will take place, the Army believes that this IRA will have no adverse impact on any endangered species or migratory birds, or on the protection of wildlife habitats.

Moreover, the Army has separately determined that this IRA will not change the physical characteristics of RMA in a manner that will have significant effect on the natural drainage of RMA for floodplain management, recharge of groundwater, and the operation and maintenance of Response Action Structures.

9.3.3 Performance, Design or Other Action-Specific ARARs

Description

Performance, design or other action-specific requirements set controls or restrictions on particular kinds of activities related to the management of hazardous substances, pollutants, or contaminants. These action-specific requirements may specify particular performance levels, actions, or technologies, as well as specific levels (or a methodology for setting specific levels) for discharged or residual chemicals.

Construction of Intercept and Treatment System

(1) Air Emissions

On the remote possibility that there may be air emissions during the course of construction of the Basin F intercept and treatment system, the Army has reviewed all potential ambient or chemical-specific air emission requirements. As a result of this review, the Army found that there are, at present, no national or State ambient air quality standards currently applicable or relevant and approprate to any of the volatile or semivolatile chemicals in the groundwater found in the immediate vicinity of the area north of Basin F.

Of course, in the context of this IRA there is only a very remote chance of any release of volatiles or semivolatiles and, even if such a release did occur, it would only be intermittent and of very brief duration (because the activity that produced the release would be stopped and modified appropriately if a significant air emission were detected by the contractor's air monitoring specialist).

(2) Worker Protection

With respect to the workers directly participating in this IRA, the worker protection requirements of Section 126 of the Superfund Amendments and Reauthorization Act of 1986 shall be met through compliance with the OSHA interim final rule that appears in 51 Fed. Reg. 45654 (1986).[1]

(3) General Construction Activities

The following performance, design, or other action-specific State ARARs are selected by the Army as relevant and appropriate to this portion of the IRA and more stringent than any applicable or relevant and appropriate Federal standard, requirement, criterion, or limitation:

(i) Colorado Air Pollution Control Commission Regulation No. 1, 5 CCR 1001-3, Part III(A) (1), "Fuel Burning Equipment":

No owner or operator shall cause or permit to be emitted into the atmosphere from any fuel burning equipment, particulate matter in the flue gases which exceeds the following:

a. 0.5 lbs. per 10^6 BTU heat input for fuel burning equipment of less than or equal to 1 x 10^6 BTU/hr. total heat input design capacity;

b. For fuel burning equipment with designed heat inputs greater than 1 x 10^6 BTU per hour, but less than or equal to 500 x 10^6 BTU per hour, the following equation will be used to determine the allowable particulate emission limitation.

$$PE = 0.5\ (FI)^{-0.26}$$

Where:

PE = Particulate Emission in per million BTU heat
FI - Fuel Input in Million BTU per hour

[1] Although OSHA proposed a permanent final rule on August 10, 1987, 52 Fed. Reg. 29620, the comment period on this rule did not close until October 5, 1987.

It should be noted that, pursuant to CERCLA Section 301(f), 42 U.S.C. 9651(f), the NCP is to be amended by December 11, 1988, to provide procedures for the protection of the health and safety of employees involved in response actions.

c. 0.1 lbs. per 10^6 BTU heat input for fuel burning equipment of greater than 500 x 10^6 BTU per hour or more.

d. If two or more fuel burning units connect to any opening, the maximum allowable emission rate shall be calculated by summing the allowable emissions from the units being operated.

(ii) Colorado Air Pollution Control Commission Regulation No. 1, 5 CCR 100-3, Part III(D) (2) (b), "Construction Activities":

a. Applicability - Attainment and Nonattainment Areas

b. General Requirement

Any owner or operator engaged in clearing or leveling of land or owner or operator of land that has been cleared of greater than one (1) acre in nonattainment areas from which fugitive particulate emissions will be emitted shall be required to use all available and practical methods which are technologically feasible and economically reasonable in order to minimize such emissions in accordance with the requirements of Section III.D. of this regulation.

c. Applicable Emission Limitation Guideline

Both the 20% opacity and the no off-property transport emission limitation guidelines shall apply to construction activities; except that with respect to sources or activities associated with construction for which there are separate requirements set forth in this regulation, the emission limitation guidelines there specified as applicable to such sources and activities shall be evaluated for compliance with the requirements of Section III.D. of this regulation.

(Cross Reference: Subsections e. and f. of Section III.D.2 of this regulation.)

d. Control Measures and Operating Procedures

Control measures or operational procedures to be employed may include, but are not necessarily limited to, planting vegetation cover, providing synthetic cover, watering, chemical stabilization, furrows, compacting, minimizing disturbed area in the winter, wind breaks and other methods or techniques.

(iii) Colorado Ambient Air Quality Standards, 5 CCR 1001-14, Air Quality Regulation A, "Diesel-Powered Vehicle Emission Standards for Visible Pollutants";

a. No person shall emit or cause to be emitted into the atmosphere from any diesel-powered vehicle any air contaminant, for a period greater than 10 consecutive seconds, which is of such a shade or density as to obscure an observer's vision to a degree in excess of 40% opacity, with the exception of Subpart B below.

b. No person shall emit or cause to be emitted into the atmosphere from any naturally aspirated diesel-powered vehicle of over 8,500 lbs. gross vehicle weight rating operated above 7,000 feet (mean sea level), any air contaminant for a period greater than 10 consecutive seconds, which is of such a shade or density as to obscure an observer's vision to a degree in excess of 50% opacity.

c. Diesel-powered vehicles exceeding these requirements shall be exempt for a period of 10 minutes, if the emissions are a direct result of a cold engine start-up and provided the vehicle is in a stationary position.

d. This standard shall apply to motor vehicles intended, designed and manufactured primarily for use in carrying passengers or cargo on roads, streets and highways.

The following performance, design or action-specific State ARAR is applicable to this portion of the IRA and is more stringent than any applicable or relevant and appropriate Federal standard, requirement, criterion or limitations:

(iv) Colorado Noise Abatement Statute,
C.R.S. Section 25-12-103:

(1) Every activity to which this article is applicable shall be conducted in a manner so that any noise produced is not objectionable due to intermittence, beat frequency, or shrillness. Sound levels of noise radiating from a property line at a distance of twenty-five feet or more therefrom in excess of the db(A) established for the following time periods and zones shall constitute prima facie evidence that such noise is a public nuisance:

Zone	7:00 a.m. to next 7:00 p.m.	7:00 p.m. to next 7:00 a.m.
Residential	55 db(A)	50 db(A)
Commercial	60 db(A)	55 db(A)
Light industrial	70 db(A)	65 db(A)
Industrial	80 db(A)	75 db(A)

(2) In the hours between 7:00 a.m. and the next 7:00 p.m., the noise levels permitted in subsection (1) of this section may be increased by ten db(A) for a period of not to exceed fifteen minutes in any one-hour period.

(3) Periodic, impulsive, or shrill noises shall be considered a public nuisance when such noises are at a sound level of five db(A) less than those listed in subsection (1) of this section.

(5) Construction projects shall be subject to the maximum permissible noise levels specified for industrial zones for the period within which construction is to be completed pursuant to any applicable construction permit issued by proper authority or, if no time limitation is imposed, for a reasonable period of time for completion of project.

(8) For the purposes of this article, measurements with sound level meters shall be made when the wind velocity at the time and place of such measurement is not more than five miles per hour.

(9) In all sound level measurements, consideration shall be given to the effect of the ambient noise level created by the encompassing noise of the environment from all sources at the time and place of such sound level measurement.

In substantive fulfillment of Colorado Air Pollution Control Commission Regulation No. 1, this IRA will employ the specified methods for minimizing emissions from fuel burning equipment and construction activities. In substantive fulfillment of Colorado's Diesel-Powered Vehicle Emission Standards, no diesel motor vehicles associated with the construction shall be operated in a manner that will produce emissions in excess of those specified in these standards.

The noise levels pertinent for construction activity provided in C.R.S. Section 25-12-103 will be attained in accordance with this applicable Colorado statute.

(4) Removal of soil

There are no action-specific ARARs that pertain to the drilling or excavation of soil during the construction of the Basin F intercept and treatment IRA.

Although not an ARAR, removal of soil from the areas where the intercept and treatment system will be located will be performed in accordance with the procedures set forth in the Task No. 32 Technical Plan -- Sampling Waste Handling (November 1987) and EPA's July 12, 1985, memorandum entitled "EPA Region VIII procedure for handling of materials from drilling, trench excavation and decontamination during CERCLA RI/FS operations at the Rocky Mountain Arsenal." In general, any soils generated by drilling or excavation during the course of this IRA, either at surface or subsurface, will be returned to the location from which they originated (i.e., last out, first in). Any materials remaining after backfilling has been completed that are suspected of being contaminated based on field screening techniques,[2] will be properly stored, sampled, analyzed, and ultimately disposed of as CERCLA hazardous waste,[3] as appropriate.

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[2]The field screening techniques to be used to determine contamination are HNU, OVA, discoloration (visual) and odor). Readings or visual and odor inspection will be taken at least every five feet.

[3]It should be noted that the "land ban" provisions of RCRA Section 3004, 42 U.S.C. paragraph 6924, are not pertinent to any such excavated soil that is identified as contaminated because the disposal and storage of these soils will be undertaken solely pursuant to 42 U.S.C. paragraph 9606 and thus will be subject to the exception in 42 U.S.C. paragraph 6924(d) (4) for CERCLA response actions taken through November 9, 1988, and thereafter to the exception in 42 U.SC. 6924(j) for storage "solely for the purpose of accumulation of such quantities of hazardous waste as are necessary to facilitate proper recovery, treatment or disposal" since this waste will ultimately be subject to treatment pursuant to the ROD for the pertinent CERCLA operable unit.

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APPENDIX A

ALLUVIAL WATER QUALITY SUMMARY

Statistical(1) Summary of Groundwater Quality Data. Page 1 of 4.

Parameter	Abbreviation	Hits/Samples	Reporting Level(2, 3) (ug/l)	Range(2) (ug/l)	Mean(2) (ug/l)	Median(2) (ug/l)	Henry's Law Constant (atm-m3/mole)	Molecular Wt
Aldrin	ALDRN	7/96	0.20	0.11-2.2	0.64	0.18	$2.4x10^{-5}$	265
Alkalinity	ALK	89/89	-	$37,000-12x10^{6}$	620,000	320,000	-	-
Arsenic	AS	36/49	3.9	3.2-42	14	8.3	-	75
Arsenic-Total(4)	ASTOT	4/29	0.50	0.012-0.018	0.015	0.013	-	-
Atrazine	ATZ	0/10	6.0	-	-	-	$1.2x10^{-9}$	216
Benzene(5)	C6H6	8/56	1.3	2.4-40	17	5.7	$6.0x10^{-3}$	78
Benzothiazole(6)	BTA (BTZ)	4/19	1.1	1.6-4.0	2.4	1.6	$4.4x10^{-6}$	135
Bicarbonate	HC03	58/58	-	$110,000-5.6x10^{6}$	790,000	320,000	-	61
Bicycloheptadiene	BCHPD	2/8	1.0	20-100	60	-	$9.2x10^{-3}$	92
Cadmium	CD	0/31	5.2	-	-	-	-	112
Calcium	CA	145/149	130	1,000-810,000	280,000	240,000	-	40
Carbon Tetrachloride	CCL4	0/62	2.4	-	-	-	$2.4x10^{-2}$	154
Chlordane	CLDAN	0/8	0.15	-	-	-	$9.6x10^{-5}$	409
Chloride	CL	254/255	20,000	$8,900-15x10^{6}$	$2.0x10^{6}$	$1.0x10^{6}$	-	35
Chlorobenzene	CLC6H5	2/58	0.58	5.3-29	17	-	2.6	113
Chloroform	CHCL3	17/50	1.4	4.4-70,000	9,600	86	$2.9x10^{-3}$	119
Chlorophenylmethyl sulfide	CPMS	26/115	20	1.5-240	56	25	$1.9x10^{-3}$	159
Chlorophenylmethyl sulfone	CPMS02	78/104	20	2.6-990	140	43	$1.2x10^{-7}$	191
Chlorophenylmethyl sulfoxide	CPMSO	25/124	20	2.9-40	21	16	$1.5x10^{-7}$	175
Chromium	CR	4/26	6.0	16-75	39	26	-	52
Conductivity(7, 8)	COND	170/170	-	300-74,000	9,700	4,400	-	-
Copper	CU	5/31	7.9	8.7-24	14	10	-	64
Dibromochloropropane	DBCP	102/300	0.20	0.15-51	7.0	3.0	$3.1x10^{-4}$	236
Dichlorodiphenylethane	PPDDE	0/46	0.05	-	-	-	$1.1x10^{-4}$	318
Dichlorodiphenyl trichloroethane	PPDDT	1/39	0.07	0.07	-	-	$9x10^{-5}$	355

(1) Only data from alluvial wells was used. Zero values not included in statistical summary.
(2) Reporting level, range, mean, median rounded to two significant figures when possible.
(3) Most common reporting limit. Some hits may be lower than detection limit indicated.
(4) 0.93 value was not included in statistical summary.
(5) 500 value was not included in statistical summary.
(6) Includes data for BTA & BTZ.
(7) $12x10^{6}$, 8, 15 values were not included in statistical summary.
(8) Units are micromhos/centimeter.

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Statistical[1] Summary of Groundwater Quality Data. Page 2 of 4.

Parameter	Abbreviation	Hits/Samples	Reporting Level(2, 3) (ug/l)	Range(2) (ug/l)	Mean(2) (ug/l)	Median(2) (ug/l)	Henry's Law Constant (atm-m3/mole)	Molecular Wt
1,1-Dichloroethane	11DCLE	10/58	1.2	1.3-17	5.5	3.0	$6x10^{-4}$	99
1,2-Dichloroethane	12DCLE	13/58	0.61	0.83-170	42	7.6	$1.3x10^{-3}$	99
1,1-Dichloroethylene	11DCE	1/57	1.1	1.4	-	-	$3.4x10^{-2}$	97
1,2-Dichloroethylene	12DCE	1/62	1.2	3.1	-	-	$6.6x10^{-3}$	97
Dicyclopentadiene	DCPD	90/220	10	2.0-1,100	260	130	$1.9x10^{-2}$	132
Dieldrin	DLDRN	52/104	0.20	0.08-8.0	1.3	0.57	$1.4x10^{-5}$	381
Diisopropylmethyl phosphonate	DIMP	239/246	10	10-4,600	760	570	$4.7x10^{-5}$	193
Dimethyldisulfide	DMDS	2/60	1.8	4.0-4.7	4.4	-	$7.3x10^{-3}$	94
Dimethylmethylphosphate	DMMP	5/52	15	23-310	89	23	NA	124
Dithiane	DITH	81/114	20	2.0-100	34	23	NA	120
Endrin	ENDRN	30/107	0.20	0.07-23	2.7	1.0	$4.4x10^{-7}$	381
Ethylbenzene	ETC6H5	13/64	1.3	0.88-8.6	3.9	3.3	$6.4x10^{-3}$	106
Fluoride	F	214/287	100	1,000-16,000	3,100	2,600	-	42
Hardness ($CaCO_3$)	HARD	140/140	-	$63,000-6.9x10^{6}$	$1.4x10^{6}$	980,000	-	-
Hexachlorocyclopentadiene	CL6CP	3/42	0.07	0.14-0.33	0.24	0.24	0.014	273
Iron[9]	FE	5/36	0.01	0.013-0.022	0.015	0.014	-	56
Isodrin	ISODR	6/108	0.50	0.72-1.3	0.96	0.73	$4.8x10^{-4}$	365
Lead	PB	0/43	19	-	-	-	-	207
Magnesium	MG	150/151	400	800-850,000	150,000	100,000	-	24
Malathion	MLTHN	0/10	8.0	-	-	-	$7.2x10^{-8}$	330
Manganese[10]	MN	21/25	0.50	0.033-28,000	6,100	1,500	-	55
Mercury	HG	5/27	0.24	0.26-0.35	0.30	0.26	-	201
Mercury-Total	HGTOT	4/12	2.0	2.4-4.0	3.1	2.9	-	-
Methylene Chloride[11]	CH2CL2	9/56	5.0	5.2-200	74	39	$2.6x10^{-3}$	85
Methylisobutyl ketone	MIBK	5/62	13	14-130	39	15	$1.1x10^{-4}$	100
Nitrate[12]	NIT	101/163	0.05	0.019-100,000	4,000	76	-	62
Oxathiane	OXAT	50/122	20	1.6-34	12	11	NA	104

(1) Only data from alluvial wells was used. Zero values not included in statistical summary.
(2) Reporting level, range, mean, median rounded to two significant figures when possible.
(3) Most common reporting limit. Some hits may be lower than detection limit indicated.
(9) 25,000 value not included in statistical summary.
(10) $13x10^6$ value not included in statistical summary.
(11) 560 value not included in statistical summary.
(12) $1.3x10^6$ value not included in statistical summary.
NA - Not available

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Statistical(1) Summary of Groundwater Quality Data. Page 3 of 4.

Parameter	Abbreviation	Hits/Samples	Reporting Level(2, 3) (ug/l)	Range(2) (ug/l)	Mean(2) (ug/l)	Median(2) (ug/l)	Henry's Law Constant (atm-m3/mole)	Molecular Wt
pH(13,14)	PH	159/159	-	6.2-8.5	-	7.3	-	-
Potassium	K	149/172	1,000	1,500-76,000	16,000	9,100	-	39
Sodium	NA	189/189	-	$7,400-25x10^{6}$	$1.4x10^{6}$	620,000	-	23
Sulfates	S04	223/226	50,000	$32,000-18x10^{6}$	960,000	450,000	-	96
Supona	SUPONA	0/10	7.0	-	-	-	$3.8x10^{-9}$	360
Tetrachloroethylene	TCLEE	22/57	1.3	2.1-350	60	32	$2.6x10^{-2}$	166
Toluene(15)	MEC6H5	10/59	1.2	2.0-8.4	5.8	5.7	$6.6x10^{-3}$	92
Total Organic Carbon	TOC	37/43	3,000	0.01-210,000	52,000	28,000	-	-
1,1,1-Trichloroethane	111TCE	0/58	1.7	-	-	-	$1.4x10^{-2}$	133
1,1,2-Trichloroethane	112TCE	2/58	1.0	1.1-5.8	3.5		$9x10^{-4}$	133
Trichloroethylene	TRCLE	23/61	1.1	1.3-69	14	7.4	$9.1x10^{-3}$	132
Unknown	UNK055 (16)	-	30	-	-	-	-	-
Unknown	UNK064	-	200	-	-	-	-	-
Unknown	UNK104	-	400	-	-	-	-	-
Unknown	UNK161	-	2,000	-	-	-	-	-
Unknown	UNK162	-	600	-	-	-	-	-
Unknown	UNK515	-	7.0	-	-	-	-	-
Unknown	UNK517	-	20	-	-	-	-	-
Unknown	UNK532	-	1.0	-	-	-	-	-
Unknown	UNK551	-	1.0	-	-	-	-	-
Unknown	UNK563	-	20	-	-	-	-	-
Unknown	UNK575	-	10	-	-	-	-	-

(1) Only data from alluvial wells was used. Zero values not included in statistical summary.
(2) Reporting level, range, mean, median rounded to two significant figures when possible.
(3) Most common reporting limit. Some hits may be lower than detection limit indicated.
(13) Standard units.
(14) 730 value not included in statistical summary.
(15) 340 value not included in statistical summary.
(16) The numbers listed for unknowns correspond to their retention times.

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Statistical(1) Summary of Groundwater Quality Data. Page 4 of 4.

Parameter	Abbreviation	Hits/Samples	Reporting Level(2, 3) (ug/l)	Range(2) (ug/l)	Mean(2) (ug/l)	Median(2) (ug/l)	Henry's Law Constant (atm-m3/mole)	Molecular Wt
Unknown	UNK579 (16)	-	50	-	-	-	-	-
Unknown	UNK582	-	40	-	-	-	-	-
Unknown	UNK586	-	10	-	-	-	-	-
Unknown	UNK587	-	100	-	-	-	-	-
Unknown	UNK588	-	50	-	-	-	-	-
Unknown	UNK591	-	70	-	-	-	-	-
Unknown	UNK592	-	20	-	-	-	-	-
Unknown	UNK594	-	200	-	-	-	-	-
Unknown	UNK596	-	20	-	-	-	-	-
Unknown	UNK597	-	20	-	-	-	-	-
Unknown	UNK600	-	100	-	-	-	-	-
Unknown	UNK602	-	10	-	-	-	-	-
Unknown	UNK603	-	20	-	-	-	-	-
Unknown	UNK604	-	7.0	-	-	-	-	-
Unknown	UNK605	-	70	-	-	-	-	-
Unknown	UNK607	-	7.0	-	-	-	-	-
Unknown	UNK608	-	9.0	-	-	-	-	-
Unknown	UNK610	-	30	-	-	-	-	-
Unknown	UNK615	-	10	-	-	-	-	-
Unknown	UNK617	-	20	-	-	-	-	-
Unknown	UNK621	-	7.0	-	-	-	-	-
Unknown	UNK635	-	20	-	-	-	-	-
Vapona	DDVP	0/10	9.0	-	-	-	$2.0x10^{-7}$	221
m-Xylene	13DMB	6/64	1.4	1.6-8.7	5.3	2.1	$5.6x10^{-4}$(17)	106
Xylenes	XYLEN	9/64	2.5	1.5-54	9.1	3.1	$5.6x10^{-4}$(17)	106
Zinc	ZN	25/31	20	28-200	65	50	-	65

(1) Only data from alluvial wells was used. Zero values not included in statistical summary.
(2) Reporting level, range, mean, median rounded to two significant figures when possible.
(3) Most common reporting limit. Some hits may be lower than detection limit indicated.
(16) The numbers listed for unknowns correspond to their retention times.
(17) Combined value for all xylenes.

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APPENDIX B

TREATMENT TECHNOLOGIES FOR REMOVAL OF INORGANIC COMPOUNDS

The technologies discussed in this appendix are appropriate for treating inorganic compounds. At this time inorganics are not considered to pose contamination problems in the groundwater north of Basin F. In the event inorganic contaminants become a problem, the technologies presented in this section would be appropriate. Because of the extreme hardness of the water, one or more of these methods may be required as a pretreatment step to reduce the water hardness.

Activated Alumina

Activated alumina is an adsorption process that is used to remove small amounts of inorganics, primarily fluorides and arsenic, from potable water and process waste waters (Rubel, 1980; Frankel & Juergens, 1980). Research indicates that selenium can also be removed by this process (Yuan et al; 1983). The activated alumina process is fairly specific to fluoride removal and is often used as a polishing step on water that has already been treated in another process.

Typically, an activated alumina system consists of a closed cylindrical vessel filled with granular activated alumina. The raw water is introduced to the column in either an upflow or downflow mode. As the water passes through the column, fluorides and other ions are adsorbed onto the alumina. The treated water is then discharged from the other end of the column.

The fluoride adsorption process is pH dependent, and optimum removal of fluoride ions occurs around a pH of 5.7 (COE, 1987a). As the ions adsorb, the pH of the effluent increases. When the pH rises to about 6.5 the column is regenerated. Regeneration is accomplished by backwashing the column with a caustic solution (typically 1 to 4 percent) to remove the adsorbed ions. Then an acid solution is applied to lower the pH to 5 (Western Filter, 1987). This regeneration step can be set up to operate automatically. Assuming the regenerant solution is 1 percent caustic, it will contain approximately 500 to 600 mg/l of fluoride at the end of the regeneration cycle (COE, 1987a). Attrition losses through regeneration should be approximately 3 percent when 1 percent caustic is used (Rubel & Williams, 1980).

An activated alumina system has been evaluated (Rubel & Hager, 1978) and designed (Black & Veatch, 1980) for fluoride removal at the North Boundary Containment/Treatment System. An increase in the maximum operating level from 2.4 mg/1 to 4.0 mg/1 eliminated the need for removal of fluoride.

An additional consideration is that arsenic is known to preferentially adsorb onto activated alumina and decrease fluoride capacity. If the groundwater being treated contains appreciable levels of arsenic, this could cause problems. Activated alumina systems are easy to operate and have a proven operating history. Capital and operating costs are low.

Advantages of an activated alumina treatment system are:

- The process is simple to operate;
- Capital and operating costs are low; and
- The process is selective for arsenic, fluoride, and selenium.

Disadvantages are:

- The process is pH dependent, so pH adjustment may be necessary; and
- The process produces a waste stream of dilute caustic that may require additional treatment.

<u>Electrodialysis</u>

Electrodialysis is a membrane process that is used to remove ionic compounds from contaminated liquid streams. A typical electrodialysis cell consists of an anode and a cathode on opposite sides of the cell. These are separated by an anion permeable membrane near the anode and a cation permeable membrane near the cathode. An electrical charge is applied across the cell and as the water flows through the channel between the two membranes, the positively charged ions are drawn through the cation permeable membrane to the cathode. Likewise the negatively charged ions are drawn to the anode. As a result there is a significant reduction in ionic compound concentrations in the intermediate channel containing the treated effluent.

Electrodialysis systems operate at low pressures, in the 40 pounds per square inch, gauge (psig) range. The main operating cost is the electricity necessary for separation of the ionic species. An electrodialysis system generally consists of many cells stacked in parallel (Viessman & Hammer, 1985). Electrical resistance in the cell stacks decreases as the temperature increases. For every 1 degree celcius (^{o}C) increase in water temperature, the power consumption is lowered by 2 percent (COE, 1987a).

Softening as a pretreatment step is not necessary but generally increases the system capacity and reduces power requirements (COE, 1987a). The resultant waste side streams consist of the anion and cation concentrated streams and typically are approximately 10 percent of the influent stream. Generally these two streams are combined for disposal; however, they can be processed separately. In any case, further treatment of the waste stream may be required prior to disposal as it contains concentrated amounts of the contaminating ions.

The electrodialysis equipment is cleaned automatically by periodic electrical reversal. The direct current flow is reversed and the diluting and concentrating streams are interchanged to cause cleaning and descaling of the membranes (COE, 1987a).

Electrodialysis is used primarily to remove inorganic species, although polar organic compounds of low molecular weight, such as short-chain carboxylic acids, are also removed readily. The long-chain organics, such as those identified in the groundwater, would pass through the system unaffected.

This technology is well established for removing inorganics in brackish water and recovering metals from plating rinses (USEPA, 1983). The method is complex and requires skilled operating personnel. The capital costs are very high.

An advantage of an electrodialysis system is:

- o It can be designed to remove specific components by using selective membranes.

Disadvantages of the process are:

- Pretreatment is often necessary to prevent fouling of the membranes;
- Periodic replacement of the membranes is often required;
- Capital costs are high;
- A skilled operator is required to operate the complex equipment and controls;
- The waste stream may require further treatment; and
- The operating costs are high.

Evaporation

Evaporation is a process in which volatile liquids such as water are removed from a waste stream, leaving behind the nonvolatile components. This is an effective way to remove inorganics from water and is often used to reduce the volume of a waste stream and/or convert it into a solid for easy disposal. Evaporation may be used to treat the contaminated groundwater directly or the waste side streams from other treatment processes. There are two basic types of evaporators, mechanical and solar.

Mechanical evaporators generally consist of a large vessel surrounded by a heating jacket. The contaminated water is brought into contact with the heated walls of the vessel where evaporation of the liquid occurs. The reduced waste stream (either a sludge or a solid) is removed from the bottom of the vessel (Perry & Chilton, 1973). Mechanical evaporators are used effectively for treatment of waste streams containing metals, radionuclides, fluorides, and selenium (HPD, undated). The installations are fairly large and require appreciable amounts of energy for heating. Dilute streams such as as contaminated groundwater are normally reduced in a preliminary treatment process such as electrodialysis, reverse osmosis, or ultrafiltration before evaporation (Harkins, 1987). This reduces the amount of fluid to be evaporated, thereby reducing heating costs.

On a less elaborate level, solar evaporation, particularly in arid regions, can be an inexpensive and easy way to reduce the water content of waste streams. The annual pan evaporation rate in the Denver area is 20 to 40

inches per year (COE, 1987a). To treat the entire waste stream of 150 gpm, an evaporation pond of approximately 150 acres would be required, based on an evaporation rate of 20 inches per year. A more logical use for evaporative treatment would be to reduce the volume of a concentrated side stream from another treatment process. This would significantly reduce the surface area of the evaporation pond. In addition, if the concentrated salts that remain are considered to be a hazardous waste, the pond would require a double liner with an intermediate leachate detection system (COE, 1987a).

Evaporators have been used successfully in many applications. The units are reliable and can handle variations in the volume of water to be treated. Capital and operating costs for mechanical evaporators are usually high because of the size and energy requirements. In contrast, costs for solar evaporators can be quite low.

The Army may not hold water-use rights in Colorado; therefore, any groundwater that is evaporated might have to be replaced. The evaporated water could be condensed and used to recharge the aquifer, or it could be replaced with purchased water from a municipality.

Some advantages of the evaporation process are:

- It has proven reliability;
- No liquid waste streams are generated that require further treatment;
- A solar evaporator has low capital and operating costs; and
- A solar evaporator requires no operators.

Some disadvantages are:

- Volatile organics will be lost to the atmosphere;
- Mechanical evaporators require trained operators;
- Mechanical evaporators produce a solid or sludge waste stream that must be disposed;
- Mechanical evaporation systems have high capital and operating costs; and

- Solar evaporators are dependent on the weather and may take an unacceptably long time to complete the process.

Filtration

Filtration is a solid-liquid separation process involving the passage of the liquid through a porous medium where the particles are removed. Initial filtration of a liquid containing appreciable amounts of suspended solids will prevent plugging of downstream processes in a treatment train. The process is frequently used to polish water treated by other processes, such as coagulation/flocculation or precipitation.

There are two general types of filtration systems used for aqueous streams, granular media filtration and strainer filtration. Granular media filters trap the solids within the pores or body of the media. Strainer filters capture the solids at the surface of the medium and frequently form a solids cake of increasing thickness. Precoat filters are a combination of granular media and strainer filtration, in which a coating of a granular material is applied either to the filter septum or within the filter. The pore diameters in the filter are thereby reduced and the filter becomes more effective at removing particles. A special type of strainer filter, the ultrafilter, is capable of removing extremely small particles and large organic molecules.

The waste stream associated with filters can be either a slurry or a solid, depending on the method used to clean the filter. Backwashing is a process in which clean water is forced backwards through the filter, forcing the accumulated solids off the filter. The backwash water is removed and is usually dewatered before disposal. Precoat filters have the ability to be "backwashed" with air or with a vibrator instead of water. This results in a solid waste side stream instead of a liquid stream, which may be easier to dispose.

The South Plants groundwater treatment pilot plant at RMA used a granular media filter to remove solids resulting from the softening process (S-R, 1983). Filtration can also be used as a pretreatment step for other treatment processes. It is an easy and inexpensive way to reduce the solids

concentration in a waste stream. Groundwater contains very few contaminants associated with particulates; therefore, filtration would be most applicable for post treatment or side stream treatment. Filters can handle large variations in flow rates.

Advantages of filters are:

- The process is easy to operate;
- The units are generally quite compact;
- The process has proven reliability; and
- The capital and operating costs are low.

Disadvantages for the process include:

- The process is effective only for contaminants associated with particulates; and
- The process generates a waste side stream that may require further treatment.

Ion Exchange

Ion exchange processes are used for a wide range of applications, including commonly recognized systems such as demineralizers and water softeners. The goal of an ion exchange system is to remove undesirable ions of a certain type (or types) from a solution and replace them with more acceptable ions (Clark et al., 1971). This type of system is generally only applicable to compounds that will dissociate into ions. The undesirable ions that have collected on the ion exchange medium are later removed in a concentrated waste stream as part of the regeneration process.

The system generally consists of a column packed with an ion exchange material. The ion exchange material is commonly a synthetic resin in bead form, although in some cases naturally occurring aluminum silicate clays or zeolites are used. The raw water is fed through the column and the undesirable ions are exchanged for more desirable ions on the resin. If a solution has both anions and cations to be removed, two different types of resins are used. These can either be placed in one column as a mixed bed resin or they can be placed in separate columns in series.

In order to adequately evaluate any treatment process, good information on the water quality must be available. For ion exchange systems, this is required to properly select the resin type and to determine the resin capacity. This is very important since resin costs range from $15 per cubic foot for natural occurring materials to over $150 per cubic foot for special resins. Resin types significantly affect operation and maintenance cost estimates.

The resins can be regenerated by flooding the column with a concentrated solution of the original ions, causing them to replace the undesirable ions retained on the resin surface. The recharging solution for this process is very strongly acidic or basic, depending on the resin. The resultant waste stream will usually require neutralization before disposal. In addition, the waste stream contains the undesirable ions in a much more concentrated form than in the original stream.

Ion exchange systems have been used successfully in many applications. The equipment is fairly easy to operate and can adapt to varying flowrates.

Some advantages of ion exchange systems are:

- It is an easy process to operate; and
- It has proven reliability.

Disadvantages are:

- Capital costs can be relatively high; and
- The strong caustic and acid regenerates produce sidestreams that need further treatment.

Precipitation

Precipitation is the process of making dissolved chemical constituents insoluble so they can be removed by sedimentation. Precipitation and clarification are most often used on waste streams that have high concentrations of metals, suspended solids, or very high molecular weight organics.

Precipitation is usually accomplished by chemical addition to the liquid stream that increases the pH of the solution, resulting in a reduction in the solubility of many contaminants (USEPA, 1983). Because of the required chemical additions, the effluent stream is often quite basic.

Metals are removed with alkaline compounds such as lime, caustic soda (sodium hydroxide), or sulfides of more acceptable metals. Fluorides are removed with lime. Frequently, the precipitates are flocculated into larger particles prior to sedimentation. The waste produced by this process is a sludge that must be removed from the bottom of the settling basin or tank. If the contaminated water contains hazardous wastes, the sludge may also be a hazardous waste that requires special disposal.

Softening is a variation of the precipitation process. Hardness is removed by adjusting the pH of the water to drive out calcium as calcium carbonate and magnesium as magnesium hydroxide (S-R, 1983). Again, the precipitates are removed as sludge.

The advantage of using water softening, clarification, and filtration as a pretreatment for other processes was investigated at the South Plants Groundwater Treatment Pilot Plant (S-R, 1983). These processes were used for hardness reduction and suspended solids removal, and produced 2 to 5 gallons of sludge per 10 gallons of raw water.

The results of the study showed that softening and clarification were not impeded by the presence of organic contaminants. Some organics were removed with the sludge. Removal rates of from 25 to 70 percent were noted for pesticides (aldrin, isodrin, endrin, and dieldrin). It was estimated that the sludge contained aldrin at 121 ppb, isodrin at 3.7 ppb, dieldrin at 447 ppb, and endrin at 312 ppb. The very volatile organics, such as carbon tetrachloride, were assumed to have at least partially escaped from the tank. The large volume of sludge produced became a disposal problem, although it could have been reduced by filtration, centrifugation, or evaporation. The presence of pesticides in the sludge may cause it to be classified as a hazardous waste, which would require special disposal.

Precipitation systems are easy to operate and are being used in many applications. Operating costs are tied to the amount and type of pretreatment, although in general they are quite low.

Some advantages are:

- It is relatively easy to operate;
- It has proven reliability; and
- The operating costs are low.

Some disadvantages are:

- It can be a large, multistaged process; and
- The waste stream may require further treatment and/or disposal.

Reverse Osmosis

Reverse osmosis has been discussed previously in Section 5.2. As was discussed, reverse osmosis is a membrane separation process that can reduce concentrations of dissolved organic and inorganic compounds and ions by 90 percent or more (Jhawar & Sleigh, 1975).

Deterioration of the membranes through chemical attack and fouling and plugging of the flow system may make pretreatment necessary. Pre-filtration to at least 5 microns is required, and chloride concentrations above 10,000 mg/l may cause corrosion of the process equipment (COE, 1987a). The side stream produced by this process is about 5 to 30 percent of the feed stream.

A high total dissolved solids (TDS) content will lead to a large reject stream that would require further treatment (COE, 1987a).

The effectiveness of reverse osmosis was also investigated at the South Plants Groundwater Treatment Pilot Plant, and the primary variable was the recovery rate (S-R, 1983). In this case, reverse osmosis was being used for inorganics removal. The influent water was pre-treated with softening, filtration,

organics removal, scale inhibition, and disinfection. It should be noted that selection of the proper pre-treatment requires good projected water quality data.

Results showed ion rejection rates to be very high, usually in the 90 to 99 percent range. Operating the system at 400 psig resulted in an effluent recovery rate of 50 percent and a salt rejection of 90 percent. Using a second stage, the recovery rate was increased to 75 percent with a corresponding net salt rejection rate of about 80 percent and an approximate 20 percent increase in product salinity.

The primary advantage is:

- It has the ability to remove organic molecules with a molecular weight greater than 200, inorganics, and metals.

Disadvantages include:

- The requirement for extensive pretreatment, depending on waste characteristics;
- A membrane life of 2 to 3 years;
- High capital costs;
- The requirement for sophisticated control equipment; and
- The production of a concentrate stream that will require treatment and disposal.

APPENDIX C
COMMENTS AND RESPONSES
ON ALTERNATIVES ASSESSMENT

Shell Oil Company

c/o Holme Roberts & Owen
Suite 1800
1700 Broadway
Denver, CO 80290

May 31, 1988

Office of the Program Manager
for Rocky Mountain Arsenal
ATTN: AMXRM-IA: Mr. Ali Alavi
Building E-4460
Aberdeen Proving Ground, Maryland 21010-5401

Dear Mr. Alavi:

Enclosed herewith are Shell Oil's comments on Draft Final Groundwater Intercept and Treatment System North of Basin F, Interim Response Action Alternatives Assessment.

Sincerely,

C.K. Hahn for

R. D. Lundahl
Manager Technical
Denver Site Project

RDL:ajg

Enclosure

cc: (w/enclosure)
Office of the Program Manager for Rocky Mountain Arsenal
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Aberdeen Proving Ground, Maryland 21010-5401

Office of the Program Manager for Rocky Mountain Arsenal
ATTN: AMXRM-TO: Mr. Brian L. Anderson
Commerce City, Colorado 80022-2180

Office of the Program Manager for Rocky Mountain Arsenal
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RESPONSES TO COMMENTS OF
SHELL OIL COMPANY ON
DRAFT FINAL GROUNDWATER INTERCEPT AND TREATMENT SYSTEM
NORTH OF BASIN F
INTERIM RESPONSE ACTION ALTERNATIVES ASSESSMENT

GENERAL COMMENTS

Comment: The system recommended in this Draft Assessment of 8-10 recharge wells "located approximately 200 feet hydraulically downgradient of the extraction wells" is ill-advised. Such systems are very desirable in some cases, but not in the case of the Groundwater Intercept and Treatment System North of Basin F. In this particular system, recharging the treated water between the extraction wells and the contaminated alluvial aquifer in Section 26 would reduce the system's effectiveness in removing groundwater contamination.

The water table at, and downgradient of, the proposed intercept location has a very mild gradient. As shown in Volume II of the June 1987 "Rocky Mountain Arsenal North Boundary Containment/Treatment System Operational Assessment Report," groundwater levels in the proposed extraction system location are only about two feet higher than they are 3000 feet downgradient towards the North Boundary System. The recharge system recommended in this Draft Assessment will prevent contaminated groundwater in this area from being drawn towards the extraction wells. Drawing contaminated groundwater from the Section 26 aquifer towards the proposed Basin F Intercept System extraction wells is an advantage and should not be purposely prevented by constructing the recharge system as recommended. Only two or three feet of drawdown along the extraction system would be sufficient to draw in contaminated water from the north for a significant distance under current conditions. As long as groundwater flows from Section 26 south towards the proposed extraction system, groundwater flowing from Basin F would still be effectively intercepted by the extraction system.

Another reason for not creating a recharge mound adjacent to the extraction wells relates to the uncertainty concerning groundwater flow in the area and the generally falling water table. Perhaps the most reliable estimates of groundwater flow through the proposed intercept location come from determining the chloride mass balance. This approach results in flow estimates of only about 10 gallons per minute through the proposed intercept system. The falling water table shows that the flow has been diminishing with time. This trend could be expected to continue as remediation progresses on Basin F and Basin C, thus reducing the magnitude of these sources of

recharge. If the 10 gpm estimate is reasonable, the creation of a recharge mound downgradient of the extraction system will restrict the extraction of contaminated water to the 11 gpm (or less) approaching from upgradient (that is, from beneath Basin F), thus reducing the system's effectiveness. The rest of the pumped water would have been previously treated, and injected only a short distance away. If the location of the recharge system is changed, the extraction system could draw in contaminated water from Section 26 as well as intercept the groundwater flowing beneath Basin F. Drawing in contaminated water from Section 26 would not be possible if the recharge system is implemented as proposed in the Assessment.

In conclusion, it is recommended that the recharge system be located so that the extraction system can draw in contaminated water from the downgradient aquifer. It is also recommended that less costly and simpler recharge technologies such as leach fields, shallow trenches, and/or pits be given further consideration. These technologies were apparently eliminated in the Assessment because they do not create predictable hydraulic barriers, but as explained above, the creation of a hydraulic barrier in this particular situation is undesirable.

Response: The contention that creating a recharge mound downgradient of the extraction system is inappropriate, appears to be based on two assumptions: 1) the groundwater flow rates are only 10 gallons per minute (gpm) in the area of the intercept system, and 2) the IRA should be used to capture contaminated groundwater in the region between Basin F and the North Boundary Containment/Treatment System (NBCTS). Some references in the comments to Section 26 contaminated groundwater are assumed to refer to the region in Section 23 between the NBCTS and the proposed location for this IRA.

The significance of the statement: "If the 10 gpm estimate is reasonable, the creation of a recharge mound downgradient of the extraction system will restrict the extraction of contaminated water to the 10 gpm (or less) approaching from upgradient (that is, from beneath Basin F), thus reducing the system's effectiveness" is unclear. As the focus of the IRA is to prevent the further spread of contamination from the Basin F region, a system that contains all the flow from this region, be it 10 or 100 gpm, would appear to be effective and to meet the goal of the IRA.

Additionally, the importance of quantity of estimated flow through this region is not for design purposes; rather it is needed to establish a common basis to compare alternative technologies. The flow estimate presented in this alternatives assessment will be refined during the development of the IRA Implementation Document to facilitate the design of the IRA.

Further, the assumption that the flow rate is only 10 gpm appears to be based on unpublished chloride mass balance calculations conducted by Shell. The intent of Paragraph 9.6 of the proposed Consent Decree is to base the assessment on readily available data that will avoid the collection of additional data and prevent delaying the implementation of the IRA. The mass balance calculations appear to be recent information that has not been made available for review. This type of calculation is only one of several types that can be used to estimate flow through the region; its accuracy is highly dependent on the location and point in time of the sampling events as well as the accuracy of the analytical data. The accuracy of this method to estimate the flow through this region is no greater than any other method. The flow estimate of 70 gpm through the region is based on the hydraulic conductivity obtained from pump test data and the water table gradient from the area. A previous estimate of flow by Waterways Experiment Station (May & Miller, 1980) of 73.2 gpm closely approximates the recent estimate. For the purposes of the assessment, a 70 gpm flow rate appears accurate and appropriate.

The assumption that the IRA should be used to capture contaminated groundwater in the region between Basin F and the NBCTS may be based on a misunderstanding of the focus of the IRA as presented in Section 2.0 of the Alternatives Assessment report. The objective: "initiate capture of the contaminated alluvial aquifer waters suspected to be emanating from below Basin F as soon as practicable," is not intended to imply that all contaminated groundwater from Basin F to the NBCTS should be addressed by this system. The intent of this IRA is to stop the further spread of contaminants which may be emanating from below Basin F and migrating via the alluvial groundwater. Any capture of contaminated water downgradient of the proposed location for the IRA would be a benefit of the system, but is not the objective of the system. Further, this benefit or any additional benefits not strictly related to the stated objective should not override the basic objective of the system. The specific objective statement in Section 2.0 has been modified to clarify this point.

SPECIFIC COMMENTS

Comment 1: Page 1, third paragraph

In the first line, insert proposed before Consent Decree.

Response: Proposed has been inserted in the text before Consent Decree.

Comment 2: Page 2, first paragraph under 2.0

This paragraph should be restated to say that the purpose of this IRA is to prevent the spread via groundwater of contaminants which may be emanating from Basin F. Remediation of groundwater in this area is an additional benefit derived from the particular action proposed.

Response: Page 2, 1st paragraph has been changed to accommodate the suggested changes.

Comment 3: Page 2, first bullet

North should be added to this sentence.

Response: The text has been changed.

Comment 4: Page 4, last paragraph

See comment #1.

Response: Same as response #1.

Comment 5: Page 6, third line under 4.2

Change is to are.

Response: The text has been changed.

Comment 6: Page 8, third full paragraph

Since the flow from the Denver Formation is undoubtedly small, there appears to be no significant need to quantify the flow. Accurately estimating the contribution would be very difficult and expensive. Merely conducting a few slug tests would not add significantly to our ability to quantify the flow, and is therefore unnecessary.

Response: Flow from the Denver Formation mudstones is probably small, but there is no evidence that the flow from the subcropping Denver sandstones is also small and insignificant. The importance of the slug tests on the Denver Formation is not to develop a complete hydrogeologic model of this region; rather it is intended to provide an estimate of the potential flow from this

unit to an intercept system located in this region. If during the operation of the IRA, it is apparent that the flow from this unit is significantly lower or greater than the estimate, extraction wells can be shut off or additional wells added, whichever is appropriate.

<u>Comment 7</u>: <u>Page 9</u>, first paragraph

Flow rates do not vary by an order of magnitude locally as stated. <u>Estimates</u> of the flow rates vary because of the inherent uncertainties in making the estimates. Perhaps the most reliable estimates are made based on chloride mass balance between Basin F and Manifold A of the North Boundary System. The chloride mass balance indicates that the flow through the proposed intercept area is on the order of 8 to 15 gpm.

<u>Response</u>: Flow rates may indeed vary locally depending on the heterogeneity of the aquifer and the variations in the bedrock surface. However, it is also true that "estimates of the flow rates vary because of the inherent uncertainties in making these estimates." This change has been added to the text.

As stated in the response to <u>General Comments</u>, the chloride mass balance estimate of flow is highly dependent on the data used for the estimate and could not be considered a more reliable estimate than the hydrogeologic estimates used for the assessment. Additionally, as no documentation of the assumptions used in this calculation have been provided, the results cannot be validated.

<u>Comment 8</u>: <u>Page 9</u>, second paragraph under 4.3.1

Many of the wells, e.g., those in the southwest quadrant of the well boundary in Figure 4-3, are likely not in the pathway of the proposed intercept system. A smaller cohort of wells, located near and north of the proposed intercept site, should be analyzed to determine if a significantly different contamination profile is indicated.

<u>Response</u>: Flow lines drawn perpendicular to the water table contours near the southwesternmost set of wells, as depicted in Figure 4-3, indicate that these wells are indeed in the pathway of the proposed intercept system. A review of the chemical data indicates that the predominant contribution of these wells to the groundwater quality north of Basin F involves either inorganic constituents or general water quality parameters. Excluding data from these wells from the water quality summary is not expected to significantly alter the target parameters presented in Table 4.3-1. Based on the current understanding of the hydrologic conditions and the contribution of the chemical data, exclusion of the southwestern set of wells does not seem appropriate for this assessment.

Comment 9: Page 9, paragraph beginning at bottom of page

This paragraph is confusing and is not technically accurate. Suggest the following: "Chemical data is available on 29 of the 48 alluvial wells. A total of 101 peaks (or potential analytes) were observed. Of these possible analytes, 68 were tentatively identified. Only 57 of the 68 analytes were quantitatively identified as being present at concentrations above their respective detection limits."

Response: The suggested change is acceptable except that the word tentatively should be left out and that reporting levels are used instead of detection limits for consistency. The 68 analytes were identified. For was substituted for on in the first sentence.

Comment 10: Page 11, 4.3.2

The meaning of "target analyte" is not explained. Also, this term has a specific meaning in the RI, which appears to be different than the meaning intended in this assessment report. Suggest that "selected analytes for purpose of characterizing aquifer contamination" be used.

What does "design value" mean in the context of this assessment report? It is not explained. Why is a design value needed for assessment?

Response: It is correct that the definition of "target analytes" is "analytes for purpose of characterizing aquifer contamination". This definition has now been incorporated in the text, but we prefer using the term "target analyte" throughout the text.

Design values were used for the conceptual designs developed in this report. The final design values may be different from those used in this assessment. The term "design value" has been replaced with "projected influent value."

Comment 11: Page 11, first full paragraph under 4.3.2

The 70 gpm estimate of regional flow is too high. The entire flow into Manifold A has averaged less than 70 gpm, and much of that flow has been provided from aquifer storage. The assumption of 36 gpm of treated water is based on the assumption that the hydraulic barrier concept is developed. As discussed in General Comments, the development of a hydraulic barrier using treated water seems inappropriate for this intercept system.

Response: See the response to General Comments.

Comment 12: Page 12, Table 4.3-1

See comment #2.

Response: We assume that Shell refers to comment # 10, not comment # 2. Our response is the same as for comment # 10.

Comment 13: Page 13, first full paragraph

Suggest substituting the following for this paragraph: "Inorganic contaminants are not presently treated in the three RMA boundary groundwater intercept/treatment systems. Moreover, the extent, if any, of control of inorganic compounds in groundwater in the Final Remedial Plan is unknown at this time. Therefore, treatment of inorganic compounds will be considered not within the scope of this IRA. Addition of inorganic treatment can be made later if a benefit is identified in the future. The inorganic profile of groundwater at this site is relevant to this assessment since inorganics can cause scaling or fouling in certain organic treatment processes."

Response: The text has been changed to incorporate the proposed substitution.

Comment 14: Page 14, paragraph beginning at bottom of page

"...dealing with the large volume of potentially contaminated material..." should not be described as a "major disadvantage" of subsurface drains. The Army has proposed a fairly simple solution in the case of the proposed North Boundary Recharge Trenches. This solution would hopefully be useful in the case of the Basin F Intercept System as well.

Response: Soils removed during excavation activities, either at the surface or subsurface, will be returned in reverse order to the location from which they originated (i.e., last out, first in). This is described in Section 5.1.1 of the report.

Comment 15: Page 15, last paragraph

As discussed under General Comments, reversing the hydraulic gradient with the use of treated water does not appear to "produce the desired effect". The effect seems undesirable. It limits the effectiveness of the extraction system and probably increases the capital and O&M costs of the system.

Response: Reversing the hydraulic gradient with the use of treated water will not reduce the effectiveness of the extraction system; rather, it will improve the performance of the system to capture and contain contaminants migrating from the Basin F area via the groundwater, which is the "desired effect." It will not enable the system to extract water downgradient of the system in Section 23, but as explained in the response to General Comments, this is not the focus of the IRA. It is agreed that this type of system will probably increase the capital and O&M costs of the system.

Comment 16: Page 18, second paragraph

If a slurry wall were installed for the purpose of limiting the recycling of treated water, as stated, then there is no reason a slurry wall would need to be constructed 80 feet deep to penetrate the subcropping Denver sands. The recycle through the sands would be very minor, and would not justify the cost of adding an extra 40 feet to the depth of a slurry wall. Nevertheless, we agree that a slurry wall in this particular system should not be recommended.

Response: As indicated in the comment, the recycle of treated water through the Denver sands may be minor, thus minimizing the need to construct a slurry wall to penetrate the entire depth of the sand unit. However, the quantity of flow is highly dependent on the hydraulic conductivity of this sand unit and the gradient of the reverse flow.

Comment 17: Page 34, 6.1

The Consent Decree requires an assessment of this IRA but not necessarily the selection and implementation of an interim action (Section 9.1(c)).

Response: The last part of the sentence (paragraph) has been replaced with:
Paragraph 9.1 of the proposed Consent Decree (1988) states that the IRA for the system north of Basin F will be implemented as necessary. Determination to proceed with this IRA will be made in the Decision Document.

Comment 18: See General Comments.
pg 35, 6.2.2

Response: See response to General Comments.

Comment 19: Page 38, Table 6.2-1

As demonstrated at other boundary systems on the Arsenal, annual O&M costs for 8-10 recharge wells are much higher than the $7,000/year shown in the table.

Response: We agree that the presented costs are too low. The actual costs for the recharge wells at the NBCTS have been significantly higher because of high maintenance requirements caused by clogging problems. The costs for recharge wells have been adjusted and are now the same as for the injection wells.

Comment 20: Page 39, second paragraph

A solar evaporator having a surface area of a quarter of a square mile would evaporate a stream of approximately 200 gpm.

The intercept system will produce much less than 200 gpm. The entire North Boundary System produces only about 225 gpm, and most of its water comes from the First Creek drainage.

Response: The size of the solar evaporator was estimated based on a flow of 200 gpm. The corrected size, based on a flow of 70 gpm, is approximately 70 acres. The considerations listed still apply, and evaporation should therefore still not be considered as a primary treatment technology.

Comment 21: Page 41, third paragraph

Scaling in the air stripper can be accommodated by incorporating a wash system. Pilot testing of the air stripping step is unnecessary. The ability to predict the performance of an air stripper is probably better than the ability to estimate influent concentrations. An analysis should be performed to determine whether or not treatment of the off-gas is required.

Response: Page 41, third paragraph

It is true that a wash system, which creates another waste stream, can take care of scaling in the air stripper. We would, however, prefer to avoid such a system if possible. We agree that pilot testing of the air stripper is not absolutely necessary, since performance estimates can be made from existing data and adjustments can be made if scaling occurs in the full scale system. It would, however, be beneficial to run a pilot test after the carbon system is in operation and base the design on the actual influent values. Operational parameters can then be adjusted so that the air emissions satisfy discharge requirements. The influent concentration is a more critical design parameter for air strippers than for carbon adsorbers.

Off-gas compositions can be calculated for the estimated influent concentrations, but since the actual concentrations will be different it is recommended that the air discharges are determined from the pilot study when the influent concentrations are known.

Comment 22: Page 45, 7.1

See General Comments and comments # 7 and # 11.

Response: See response to General Comments and comments No. 7 and 11.

Comment 23: Page 47, third bullet

See comment # 6.

Response: See response to comment No. 6.

Comment 24: Page 48

Paragraph beginning on bottom of page. See Comment No. 6.

Response: See response to comment No. 6.

Comment 25: Page 49, 4.2

Water quality data would have to deviate considerably to affect the selection of processes and sizing of equipment. Therefore water quality data should be investigated only in the area of the proposed extraction system. Air emissions from the air stripper are very easy to calculate based on feed water quality. The results can then be checked in a preliminary model for the effect on air quality.

Response: The section should be 8.2.

Water quality data (in terms of organics concentration) do not necessarily have to deviate considerably to affect process selection and equipment size. Deviations may be due to the presence or lack of volatiles, a difference that may correspond to the need for an air stripper, and possibly vapor phase treatment in the treatment system. Groundwater from a wider area than that adjacent to the extraction system will be treated and water quality data for the entire area involved should therefore be investigated.

It is true that air emissions are easily calculated from influent concentrations and design removal efficiencies. Such estimates are, however, beyond the scope of this report.

6 JUN

STATE OF COLORADO

COLORADO DEPARTMENT OF HEALTH
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Roy Romer
Governor

Thomas M. Vernon, M.D.
Executive Director

June 3, 1988

Mr. Donald Campbell
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RMA Contamination Cleanup
AMXRM-EE, Building E 4460
Department of the Army
Aberdeen Proving Ground, MD 21010 - 5401

RE: State Comments on Draft Final Groundwater Intercept and Treatment System North of Basin F, Interim Response Action Alternatives Assessment, May, 1988

Dear Mr. Campbell:

Enclosed are the State's comments on the above referenced report. If you have any questions regarding the comments, please contact Mr. Jeff Edson.

Sincerely,

David C Shelton by

David Shelton
Director, Hazardous Materials and
Waste Management Division

cc: Dave Anderson
Chris Hahn, Shell Oil Co.
Edward McGrath, Holme, Roberts & Owen
Connally Mears, EPA
Mike Gaydosh, EPA

881196 - 1/2

RESPONSES TO COMMENTS OF
COLORADO DEPARTMENT OF HEALTH ON
DRAFT FINAL GROUNDWATER INTERCEPT AND TREATMENT SYSTEM NORTH
OF BASIN F
INTERIM RESPONSE ACTION ALTERNATIVES ASSESSMENT

GENERAL COMMENTS

Comment 1: The groundwater intercept and treatment system north of Basin F must be constructed pursuant to the "Modified Basin F Closure Plan". Therefore, all plans must be submitted for approval by the Colorado Department of Health prior to implementation.

Response: The groundwater intercept and treatment system north of Basin F will be constructed pursuant to the proposed Consent Decree; plans will be submitted in conjunction with the IRA process contained therein.

Comment 2: The State agrees that the localized hydraulic characteristics of the Denver Formation north of Basin F have not been fully defined. An enhanced characterization of localized hydraulic interconnections between the Alluvial and Denver Formations is needed to determine the most effective location for the extraction system. The extraction system must be sited such that it intercepts the maximum amount of contamination possible in the Alluvial aquifer and uppermost Denver Formation. Therefore, additional data collection is needed prior to initiating construction of the intercept system.

Response: Extensive collection of additional data on the hydraulic interconnections between the alluvium and the Denver Formation would be costly, time consuming, and beyond the scope of the IRA. The maximum benefits of any IRA are achieved with as early an implementation as possible. This IRA is not the Final Response Action for Basin F and the contaminated groundwater in the area. If subsequent investigations demonstrate that contaminants from Basin F have migrated into the upper Denver aquifers, the IRA will either be modified to contain the contaminants in these aquifers or the Final Response Action will be designed to address this contamination, whichever is more practicable.

Comment 3: The U.S. Army COE report entitled, Feasibility Analysis, Basin F Interim Well System, Rocky Mountain Arsenal, December, 1987 was not provided to the State. The State must be afforded the opportunity to review all pertinent documents if it is to provide viable comments with respect to the preliminary analysis and selection of intercept/treatment options.

Response: The report was prepared for PMO by COE and is not a product subject to review by the Organizations and the State. The document is available at the RIC center as report number RIC 88162R03.

Comment 4: The State does not agree that the extraction system should be limited to a lateral width of 1000 feet. The plume of contamination north of Basin F is known to be over 1500 feet. A 1500 foot extraction system would most likely intercept the majority of contaminants in the uppermost aquifer(s). Accordingly, the preliminary conceptual analysis, design, and costing should be made based on a design width of at least 1500 feet.

Response: The extraction system is proposed to span the bedrock channel, the primary alluvial groundwater migration path in this area, and adjacent areas of saturated alluvium. As shown in Figure 4-2, the channel contains up to 10 feet of saturated alluvium, while outside the channel the saturated thickness is only 1 to 2 feet. The interceptor wells placed in and adjacent to the bedrock channel, when pumped at the appropriate rate, will draw the water table down and effectively dewater the alluvium for a distance outside the channel. This will increase the effective width of the interceptor system, and additional wells installed to completely span the saturated alluvium will not be necessary. The details of the interceptor system are beyond the scope of the IRA Alternatives Assessment, but will be presented in the IRA Implementation Document.

Comment 5: The Basin F intercept system is proposed to be designed for approximately a 5 year life time. As the State has previously indicated, to achieve the most effective clean-up of groundwater, a series of "pump and treat" systems within the interior of RMA must be constructed and operated. Therefore, the Basin F intercept system should be designed to operate until a complete remediation of on-site groundwater is achieved.

Response: The IRA is intended to operate until the Final Response Action has been installed. The time required has been estimated to be a minimum of 5 years.

Comment 6: The findings from operations of the North Boundary Containment System, the Northwest Boundary Containment System and the Irondale System, including any problems encountered and the effectiveness of the systems, should be used to assess alternatives for the Basin F intercept system. An analysis of these systems, a discussion of their problems, and the effectiveness of those systems should be included in this report.

Response: Experience and findings from the other treatment systems have been included in this report. The reader is referred to pages 21 and 22 (section 5.2) of this report as an example.

SPECIFIC COMMENTS

Comment 1: Page 2, paragraph 1

It is well known that the Alluvial aquifer and the Denver Formation are hydraulically interconnected and that both have been contaminated from past activities at RMA. See, e.g., the USAEWES, 1985 report and the Task 4 Final Screening Program Report. Similarly, it is admitted that the North Boundary and Northwest Boundary Containment Systems do not capture and treat all contaminated groundwater. Therefore, the introduction to this report should be modified to indicate that the Denver Formation is also contaminated and that the boundary systems do not effectively capture Denver Formation contamination.

Response: It is beyond the scope of this report to summarize all possible contamination of the Denver Formation and the operation of the boundary systems. The focus of this IRA is the containment of contamination that may be emanating from below Basin F.

Comment 2: Page 3, paragraph 3

Contamination has been identified in the Alluvial aquifer and the Denver Formation. That contamination continues to migrate off-site to the north and northwest. Therefore, the State does not agree that the contamination present in the groundwater immediately north of Basin F does not constitute a continuing threat to the public health and the environment.

Response: Contaminated groundwater located between the proposed location for the IRA and the North and Northwest Boundary Containment/Treatment systems "does not constitute a present threat to the public health or the environment" as the groundwater use restrictions at RMA prevent contact or ingestion of this water.

Comment 3: Page 4, paragraphs 1 and 2

It is likely that groundwater contamination upgradient from the Basin F intercept system will remain after 5 years of operations. Therefore, it makes little sense to design a system to operate for 5 years when it should be operated at least until the final remedy is implemented.

Response: We agree that the system should be operated until the final remedy is implemented. The required time period has been estimated to be a minimum of 5 years.

Comment 4: Page 4, Section 3.2

The Basin F intercept system must be designed to effectively treat all contaminants, not merely "contaminants of interest".

Response: As no chemical-specific ARARs are available for this IRA, the assessment of technologies was based on "target analytes" as defined in the report. These compounds were selected based on their concentration and frequency of occurence and were used to select processes and develop loading rates for the treatment system. Many contaminants not listed as target analytes will also be removed by the proposed IRA treatment system, since most organic contaminants are removed by carbon adsorption.

Comment 5: Page 5, Figure 4-1

The figure should indicate that the line depicting the "Basin F Boundary" is actually the fence around the basin.

Response: The figure has been changed so that the Basin F Boundary Fence now is marked.

Comment 6: Page 8, Paragraph 4

Contrary to the generalization presented in the text, some cluster wells screened in the Alluvial aquifer and zones of the upper Denver Formation indicate a vertical downward gradient. Cluster wells that show this trend include 23191, 23192, 23193, 23185 and 23186. Conversely, some cluster wells (26088 and 26089) show a potential for upward movement. Since there is some variability in direction and gradients within the Basin F area, the gradients and direction of flow for specific units should be identified.

Response: The focus of this paragraph is the amount of water that will be contributed to the interceptor wells from the Denver Formation sandstone units and not the existing gradients and directions of flow of the water in these units. When the interceptor wells are pumping, an artificial gradient will be imposed on the Denver sandstones in the area of the wells. The contribution of this water to the IRA system will be important for design considerations. As explained in the response to General Comment No. 2, the interactions between the alluvium and the Denver Formation will be investigated after installation of this IRA and will be addressed by either modifications to the IRA or the Final Response Action.

Comment 7: Page 9

The conclusions in the report regarding upper Denver Formation water quality are incorrect and should be modified or deleted. The four Denver Formation monitoring wells analyzed by the Army to estimate water quality are not representative of Denver Formation contamination. The monitoring wells selected by the Army (26132, 26139 and 26044) were reported to be "clean". Historical data in this area show contamination, specifically

Denver aquifer monitoring wells 26041, 26043, 26047, 23054 and 23056. All available data from Denver Formation monitoring wells in the area north and east of Basin F must be incorporated into the report and used to determine the most appropriate location for the intercept and treatment system.

Response: As stated previously, the focus of this IRA is to stop the spread of contamination that may be emanating from beneath Basin F. Prior to including a Denver aquifer in this IRA, it should be determined if the above-mentioned wells could have been contaminated by Basin F liquids. This determination is beyond the scope of the IRA. Any contamination of the Denver aquifer will be addressed in the Final Remedy.

Comment 8: Thirty-three of the 101 analytes detected in this assessment were eliminated from further consideration because they were not fully identified. If these analytes were detected at high concentrations or found in numerous wells, they may be important constituents of the contaminant plume and may need to be considered in assessing treatment alternatives. The data from the assessment should be presented in the report.

Response: The unknowns were identified by retention times and concentrations, and this information has been included in Appendix A of the report.

Comment 9: Page 11

Eleven identified contaminants "had no concentrations above their reporting levels" and were eliminated from further review. Please identify the eleven contaminants and explain what is meant by "reporting levels".

Response: The reader is referred to Appendix A where all contaminants, including the 11 with no concentrations above their reporting levels, are reported. Reporting levels are the reporting limits certified by USATHAMA for each specific compound or the method detection level, whichever was entered into the database.

Comment 10: Page 11

The concentrations of contaminants in the influent used to design the treatment system, were based in part on a mean concentration in selected monitoring wells. The mean concentrations may be underestimated. The treatment system should be designed based on a worse case scenario to treat unexpected loadings of contaminants. For example, the range of observed chloroform hits was shown to be 4.4 to 70,000 ppb. The influent design value was calculated to be 6300 ppb. This may result in the system having to treat contaminant loadings that are much greater than the system's design capacity.

Response: It is very unlikely that the worst-case scenario would be representative of the actual conditions. Very high (or very low) data values are usually outliers that artificially increase the mean concentrations. In actual operating systems, the groundwater concentrations are generally lower rather than higher than the mean concentrations.

The only adjustment to be made for the activated carbon adsorption system in case of higher (lower) concentrations is to change the regeneration frequency. The air stripping unit will be pilot tested prior to being included in the full scale system and the final design will be based on the pilot study results.

If modifications and/or additions to the treatment system are determined necessary or advantageous, changes will be made after the system is operational.

Comment 11: Page 41, paragraph 2

The State agrees that air emissions could be a problem if air stripping is arranged prior to carbon adsorption in the treatment system. Therefore, it should be anticipated that if an air stripper is determined to be necessary, it will require emission controls and/or will need to follow the carbon adsorption unit.

Response: Until the actual air emissions have been determined it is uncertain whether vapor phase treatment will be required. Based on pilot test results, the air discharge can be adjusted so that vapor treatment will not be required. If the air stripper is arranged prior to the carbon adsorbers, volatiles not removed in the air stripper will be removed in the adsorbers. Arranging the stripper to follow the adsorbers is also feasible. The actual arrangement will be determined after pilot testing.

Comment 12: Pages 47-49

The State agrees that more detailed information on the hydrogeologic system is necessary to effectively design the extraction system. Given that slug tests are generally not as accurate as pumping tests, the State recommends that slug tests used for the design of the intercept system be calibrated with new aquifer pumping tests conducted in wells at the proposed location of the intercept system.

Response: It is agreed that pump tests would provide more accurate aquifer hydraulic characteristics than slug tests; however, as stated in the assessment report, the cost of the pump test and the handling and disposal requirements of the pump test water make this a less attractive alternative. Slug tests will provide a

degree of accuracy sufficient for the design of the IRA. If, during operation of the IRA system, additional wells or well pumps are determined to be necessary to effectively contain the migration of contaminants, modifications to the IRA system will be made to upgrade the system to meet these requirements.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
999 18th STREET - SUITE 500
DENVER, COLORADO 80202-2405

JUN 01 1988

Ref: 8HWM-SR

Colonel W. N. Quintrell,
Program Manager
Office of the Program Manager for
Rocky Mountain Arsenal
ATTN: AMXRM-PM
Building E4460
Aberdeen Proving Ground, Maryland 21010-5401

Re: Rocky Mountain Arsenal, (RMA), Ground Water Intercept and Treatment System North of Basin F, Interim Response Action, Alternatives Assessment, Draft Final Report, May, 1988.

Dear Colonel Quintrell:

We have reviewed the above referenced report and have the enclosed comments from our contractor and staff. Please contact Mr. Connally Mears at (303) 293-1528, if there are questions on this matter.

Sincerely yours,

for RLD

Robert Duprey, Director
Hazardous Waste Management Division

Enclosure

cc: Thomas P. Looby, CDH
David Shelton, CDH
Lt. Col. Scott P. Isaacson
Chris Hahn, Shell Oil Company
R. D. Lundahl, Shell Oil Company
Thomas Bick, Department of Justice
David Anderson, Department of Justice
Preston Chiaro, EBASCO

RESPONSES TO COMMENTS OF
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY ON
DRAFT FINAL GROUNDWATER INTERCEPT AND TREATMENT SYSTEM NORTH
OF BASIN F
INTERIM RESPONSE ACTION ALTERNATIVES ASSESSMENT

GENERAL COMMENTS

Comment 1: For ease of comparison, a separate cost estimate for the carbon plus air stripping with emission controls alternative should be provided.

Response: We do not see that a separate cost of carbon plus air stripping with emission controls is needed since the cost of emission control is provided in Table 6.3-1. The primary reason for separating the costs is that the need for vapor phase treatment may be eliminated. This can be done by adjusting the removal efficiencies of the air stripper or by placing the air stripper after the carbon adsorber.

Comment 2: EPA recommends that you continue to consider some of the destructive technologies during the FS, including the chemical oxidation procedures.

Response: A variety of different destructive technologies, including oxidation, will be considered in the FS.

Comment 3: Page 13

Simply because the inorganics are not being treated in the boundary systems is not a justification for a conclusion that the same is appropriate at this location. (Upgrading of the boundary systems is being evaluated separately in another Interim Response Action.) The treatment decision must be based on an evaluation of action levels vs. alternative performance ability.

Response: No chemical-specific ARARs, which would define action levels for inorganics, are applicable for this assessment. If the need for inorganic treatment is identified, appropriate processes will be added later.

Comment 4: Page 41

Preliminary estimates are given for lime softening of 50 percent of the influent stream; why would only 50 percent be softened?

Response: We have assumed that complete hardness removal from 50 percent of the influent streams would reduce the total hardness sufficiently to avoid scaling or fouling problems. This assumption will be examined further in the design phase of the IRA.

Comment 5: Page 36

It is stated that the carbon adsorption will not remove polar compounds such as methylene chloride listed on page 12 as a target parameter with an influent design value of 51 ug/l. However, on page 40, it is stated that the carbon adsorption can remove "all of the compounds of concern." This appears to be an inaccuracy.

Response: The statement on page 36 states: "carbon adsorption is a proven treatment process for removal of organic compounds, although it will not remove polar compounds such as methylene chloride very efficiently." The statement on page 40 does not imply complete removal. Methylene chloride will be removed by activated carbon, but the adsorption capacity is very low. Consequently there is no inaccuracy between the statements.

Comment 6: Pages 40 and 45

If an air stripper were used, the methylene chloride and other polar compounds would be removed; however, the emissions control suggested is vapor phase carbon adsorption which would not capture these polar compounds. Other emissions controls might be effective.

Response: Methylene chloride and other polar compounds will be removed by vapor phase carbon even though their adsorption capacities are low. We do not, however, anticipate that methylene chloride will be a major contaminant, and the other major compounds such as trichloroethylene and chloroform are relatively easily removed by vapor phase activated carbon adsorption. If methylene chloride or other poorly adsorbable compounds are found to be present at significant levels during the pilot study, other types of emission controls will be evaluated.

Comment 7: Page 49, bottom paragraph.

If air stripping were used, emissions controls would be required to meet location and chemical-specific ARARs or risk based levels (to the maximum extent practicable).

Response: We agree that emissions controls may be required to meet location- and chemical-specific ARARs or risk based levels. This information is included in Section 8.2 of the report.

Comment 8: Pages 42 and 47

There is a discrepancy in the capital and operating costs for Alternative 1, the activated carbon adsorption system, given on page 42 and those listed on page 47. Please explain the differences.

Response: The costs presented in Table 6.3-1 are correct.

REVIEW COMMENTS

Comment 1: Page 6 (Section 4.2)

Reference is made to Figure 4-1 to show preferential contaminant migration pathways due to bedrock valleys and groundwater flow patterns. The discussion should point out the existence of a groundwater divide to the west of Basin F. Therefore, any contamination originating from Basin F would flow predominantly in a north-northeasterly direction where the proposed groundwater control system is to be located.

Response: The extent of unsaturated alluvium in the area west of Basin F can only be approximated from available data and does not demonstrate a clear groundwater divide. However, water table elevations indicate that any contamination that may have originated from below Basin F flows predominantly in a north-northeast direction to the proposed location for the IRA. The information about flow direction has been added to the text.

Comment 2: Page 11 (Section 4.3.2)

A total of 57 chemical analytes were detected in the groundwater, of which only 22 were selected as target contaminants for the IRA assessment. The rationale for eliminating the remaining 35 analytes should be discussed with specific reference to an ARARs analysis and risk-based action levels. This analysis should include evaluation of action levels/cleanup goals for each selected target contaminant. Before a final alternative selection is made, the ARARs/risk-based action levels analysis must be completed and an evaluation of the ability of the alternatives to achieve those levels must be made.

Response: There are no chemical-specific ARARs applicable to this IRA. The selection of target analytes was, as explained in Section 4.3.2, based on the frequency of detection and concentration levels of the compounds. It should be emphasized that these parameters were used only for the assessment of applicable technologies and for preliminary designs. Compounds other than those listed as target analytes will also be removed by the treatment system.

Comment 3: Page 48 (Section 8.1)

The EPA recommends that an aquifer pumping test with observation wells be performed instead of slug tests to determine the hydraulic characteristics of the alluvial aquifer in the vicinity of the intercept system. The presence of the local bedrock valley features will make it difficult to correlate information from slug tests with the previous aquifer pump test

at Well 23049. This difficulty arises because of the limitation of slug tests in providing only point estimates rather than an aerial [sic] estimate of transmissivities provided by the pumping test.

Response: It is agreed that pump tests would provide more accurate aquifer hydraulic characteristics than slug tests; however, as stated in the assessment report, the cost of the pump test and the handling and disposal requirements of the pump test water make this a less attractive alternative. Slug tests will provide a degree of accuracy sufficient for the design of the IRA. If during operation of the IRA system additional wells or well pumps are determined to be necessary to effectively contain the migration of contaminants, modifications to the IRA system will be made to upgrade the system to meet these requirements.

Comment 4: EPA recommends conduction of an Accelerated Carbon Test to confirm removal efficiencies and allow refinement of capitol [sic] and O&M costs for the Granular activated carbon treatment alternative.

Response: An Accelerated Column Test would have to be conducted with the actual influent water to be useful for design of the adsorbers. The actual influent water quality cannot be determined prior to installation of the IRA extraction system. It is very unlikely that the capital costs would be significantly changed based on test results due to the flow rate and the types of contaminants to be removed. The only benefits to be derived from the test would be estimated regeneration frequencies and possibly information on chromatographic effects in the adsorption column. The regeneration intervals can easily be adjusted after the system is in operation based on routine monitoring. The goal of timely implementation of this IRA would also be adversely affected by these studies.

APPENDIX D
COMMENTS AND RESPONSES ON
DRAFT APPLICABLE OR RELEVANT AND
APPROPRIATE REQUIREMENTS

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Fish and Wildlife Enhancement
529 25½ Road, Suite B-113
Grand Junction, Colorado 81505

TAKE PRIDE IN AMERICA

IN REPLY REFER TO:

June 2, 1988

Colonel Wallace N. Quintrell
Deputy Program Manager
Department of the Army
U. S. Army Toxic and Hazardous
Materials Agency (USATHMA)
Building 4435
Aberdeen Proving Ground, Maryland 21010-5401

Dear Colonel Quintrell:

We have reviewed the Groundwater Intercept System north of Basin F Interim Response Action Draft Applicable or Relevant and Appropriate Regulations Document. Assuming that physical/construction activities will be confined to the Basin F Intercept System (mapped as approximate location, Fig. 4-1), we can find no objection with this action that would seriously threaten wildlife of federal concern. Because the activities here mentioned will be only part of an already complex set of activities in and around Basin F, we see no need to restrict the activities to the period when bald eagles may be present. However, to the extent that construction activities may expand to a significant extent beyond the site of the Intercept System, we would reserve an additional evaluation of the scope of disturbance which could include the need to add restrictions for the protection of bald eagles.

Thank you for the opportunity to review the subject document. Please contact Rod DeWeese or Pete Gober at FTS 776-2675 if you have any questions about these comments.

Sincerely,

Lawrence R. DeWeese
for
Jeffrey D. Opdycke
State Supervisor

cc: Bob McCue, FWS
Tom Jackson, FWS
Bob Stewart, DOI
Connally Mears, EPA
Douglas Reagan, ESE

881189

RESPONSES TO COMMENTS OF
UNITED STATES DEPARTMENT OF THE INTERIOR,
FISH AND WILDLIFE SERVICE ON THE GROUNDWATER
INTERCEPT SYSTEM NORTH OF BASIN F
INTERIM RESPONSE ACTION DRAFT APPLICABLE
OR RELEVANT AND APPROPRIATE REQUIREMENTS

No comments requiring responses.

01 JUN REC'D

HOLME ROBERTS & OWEN

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May 31, 1988

E VARD J. McGRATH

Mr. Donald L. Campbell
Department of the Army
Office of the Program Manager
Rocky Mountain Arsenal Contamination Cleanup
Attention: AMXRM-EE
Building E4460
Aberdeen Proving Ground, Maryland 21010-5401

Re: Shell Oil Company Comments on the Groundwater Intercept System North of Basin F Interim Response Action Draft Applicable or Relevant and Appropriate Regulations Document

Dear Mr. Campbell:

Shell Oil Company submits these comments on the Groundwater Intercept System North of Basin F Interim Response Action Draft Applicable or Relevant and Appropriate Requirements document ("ARARs Document"), dated May 2, 1988.

AMBIENT OR CHEMICAL-SPECIFIC ARARS

Shell agrees that for the Interim Response Action ("IRA") proposed, there are no pertinent chemical-specific ARARs.

In addition, according to the Draft Final Groundwater Intercept and Treatment System North of Basin F Interim Response Action Alternatives Assessment document ("IRA Assessment"), dated May, 1988, the installation of air-stripping technology is provisionally proposed for this IRA. If this technology is determined to be practicable, the air strippers would supplement the carbon absorption treatment technology which, pursuant to the IRA, is to be initially installed. Therefore, a discussion of chemical-specific air emissions standards should be included in this review of potential ARARs.

LOCATION-SPECIFIC ARARS

Shell disagrees with the proposed selection of 40 C.F.R. § 141.5 (siting requirements for public water systems) as relevant and appropriate and therefore an ARAR. The Army does not describe why it believes that a siting requirement

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for a public water system is sufficiently similar to an IRA which is intended to pump up and recharge groundwater. According to the preamble to the proposal for section 141.5, "[t]he siting requirements of § 141.41 [the precursor of § 141.5] are designed to assure that, to the extent practicable, the location of the intake and other elements of new or expanded water supply systems will be such that the public water systems will be able to provide a continuous supply of healthful drinking water." 51 Fed. Reg. 11993 (March 14, 1975). The reasons set forth by the Army for concluding that section 141.5 is not "applicable" also indicate that the regulation is not "relevant and appropriate." Those reasons are that "[t]he Basin F intercept and treatment system does not constitute a public water system, [and] no one is drinking or is to drink water to be treated by this system." Further, the intake and other elements of new or expanded water supply systems are not sufficiently similar to the intercept and treatment system to justify selection of section 141.5 as an ARAR.

PERFORMANCE DESIGN OR OTHER ACTION-SPECIFIC ARRAS

Air Emissions. As described above, implementation of this IRA may involve the use of air-stripper technology. Such technology is designed to vaporize most organics in the groundwater being treated, and could implicate design or action-specific potential ARARs. Shell, therefore, requests that the Army expand its review of potential air-emission ARARs in order to address the possibility that the IRA may utilize gas-stripper technology.

Worker Protection. Shell supports the application of worker protection standards to this IRA. These standards, however, are not ARARs and should be deleted from an ARARs analysis.

General Construction Activities. While Shell does not object to compliance with Colorado Air Pollution Control Regulation No. 1, section III(A)(1), applicable to fuel burning equipment, it requests clarification regarding how this equipment will be used in this IRA.

Shell disagrees that Colorado Air Pollution Control Commission Regulation No. 1, section III (D)(2)(b) ("construction activities"), is an ARAR. The surface area which will be disturbed by construction activities in this IRA is less than one acre. Further, paragraphs (iii) and (iv) set forth broad narrative requirements to use controls to minimize emissions and are too general to constitute a level or standard of control relating to the degree of cleanup.

The Colorado Ambient Air Quality Standards, Air Quality Regulation A, "Diesel-Powered Vehicle Emission Standards for Visible Pollutants, is only an ARAR to the extent that motor vehicles may haul soils off-site. The regulation, by its terms, applies only "to motor vehicles intended, designed and manufactured primarily for use in carrying passengers or cargo on roads, streets and highways." See paragraph D.

Shell requests clarification of how contaminated excavated soils will be handled. According to the ARARs Document, "any soils generated by drilling or excavation during the course of this IRA, either at surface or subsurface, will be returned to the location from which they originated (i.e., last out, first in)." This activity will not be subject to a RCRA ARAR. At a minimum, for RCRA to be an ARAR for such an activity, the activity would have to involve treatment of the soil prior to depositing the soil into the excavated area. The IRA does not involve such treatment. Mere placement of hazardous wastes excavated from an area into the same area does not trigger RCRA. The EPA Region VIII June 12, 1985 memorandum, however, is unclear regarding whether contaminated soils can be placed back into the excavation or whether the soils must be drummed. The memorandum should be interpreted as requiring drumming of only the remaining soils that cannot be placed back into the excavation. In any event, the memorandum is described by EPA as a "procedure" to comply with "EPA policy." See July 19, 1985 letter from Robert Duprey to Colonel Quintrell. It therefore is not a standard, requirement, criteria or limitation and is not an ARAR.

Shell agrees that the land ban provisions of RCRA are not ARARs for the reasons set forth in the proposed decision document. In addition, mere placement of wastes back into the same excavation would not trigger RCRA for the reasons set forth above. We also have no evidence that the soils may be contaminated with those wastes that are subject to the land disposal ban.

Very truly yours,

Edward J. McGrath/cLN

Edward J. McGrath

cc: Colonel Wallace N. Quintrell
Lieutenant Colonel Scott Isaacson
Major Larrry Rouse
Kenneth E. Wiggans
Major Larry Rouse
David Anderson, Esq.
Andrew M. Gaydosh, Esq.

RESPONSE TO COMMENTS BY SHELL OIL COMPANY
ON THE GROUNDWATER INTERCEPT SYSTEM NORTH OF BASIN F
INTERIM RESPONSE ACTION DRAFT APPLICABLE OR RELEVANT AND
APPROPRIATE REQUIREMENTS

I. Ambient or Chemical-Specific ARARs

Comment 1: A discussion of chemical-specific air emission standards should be included in this document because the addition of air strippers is provisionally proposed for this IRA.

Response: The Army believes that further evaluation of the practicability of air stripping technology is needed before it would be appropriate to evaluate chemical-specific air emission standards.

II. Location-Specific ARARs

Comment 1: Shell disagrees with the proposed selection of the siting requirements for public water systems, 40 CFR Sec 141.5, as relevant and appropriate for this IRA.

Response: Although this proposed groundwater treatment system is not a public water system nor provides drinking water, the Army believes that its construction is sufficiently similar to the construction contemplated by these regulations to make them relevant and appropriate to the construction activities planned by this IRA.

III. Performance, Design or Other Action-Specific ARARs

Comment 1: Air Emissions - Implementation of this IRA may involve use of air stripper technology. Therefore, Shell requests that potential air emission ARARs be reviewed to address this possible technology.

Response: As noted above, the Army believes it is premature to review this issue at this time.

Comment 2: Worker Protection - The standards are not ARARs and should be deleted from the ARARs analysis.

Response: The Army believes that due to the statutory requirements of the Superfund Amendments and Reauthorization Act of 1986, Section 126, it is appropriate to include worker protection standards in the ARAR document.

Comment 3a: General Construction Activities - Shell requests clarification regarding how fuel burning equipment will be used.

Response: It is unknown at this time whether fuel burning equipment will be used for construction. However, likely equipment includes diesel powered generators, backhoes, front-end loaders, and drill rigs.

Comment 3b: Shell disagrees that Colorado Air Pollution Control Commission Regulation No. 1, Section III (D) (2) (b) is an ARAR.

Response: The Army believes that these regulations, while not applicable, are relevant and appropriate to the construction activities associated with this IRA. The level or standard of control established under these regulations is directed at protecting air quality from adverse effects due to construction activities. The Army believes that the construction activities to be conducted pursuant to this IRA are sufficiently similar to those intended to be controlled by this regulation for it to be relevant and appropriate in this context.

Comment 3c: The Colorado Ambient Air Quality Standards, Air Quality Regulation A, "Diesel-Powered Vehicle Emission Standards for Visible Pollutants" should only be considered an ARAR to the extent that motor vehicles haul soils off-site.

Response: The Army believes that this regulation, while not applicable to this IRA activity, is relevant and appropriate in the context of this IRA. Consistent with paragraph D of this regulation, its standards are considered relevant and appropriate to apply only to vehicles designed and manufactured primarily for use in carrying passengers or cargo on roads, streets and highways.

Comment 3d: Shell requests clarification of how contaminated excavated soils will be handled.

Response: Excavated soils will be returned to the excavated area on a last out, first in basis. Excess soils which can not be returned to the excavated area will be screened in accordance with the June 12, 1985 EPA Region VIII memorandum to determine if they are potentially contaminated. If material is determined to be potentially contaminated it will be further managed pursuant to the procedures discussed in the EPA memorandum. This subject is also discussed in the responses to comments by EPA Region VIII.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
999 18th STREET - SUITE 500
DENVER, COLORADO 80202-2405

JUN - 1988

Ref: 8RC

BY EXPRESS MAIL

Colonel Wallace N. Quintrell, Program Manager
Office of the Program Manager
for Rocky Mountain Arsenal
Department of the Army
ATTN: AMXRM-PM: Colonel Wallace N. Quintrell
Building E4460
Aberdeen Proving Ground, Maryland 21010-5401

RE: Groundwater Intercept System North of Basin F
Interim Response Action Draft Applicable or
Relevant and Appropriate Requirements (ARARs) Document

Dear Colonel Quintrell:

U.S. EPA, Region VIII received a copy of the above-referenced draft ARAR document on May 3, 1988. We have reviewed that draft document and have a number of comments. For purposes of clarity, our enclosed comments are organized into the following categories: I. Potential Contaminant-Specific ARARs; and II. Potential Location-Specific ARARs.

If you have any questions regarding this matter, please feel free to contact Jessie Goldfarb, Assistant Regional Counsel (FTS-564-7529) or Connally Mears (FTS-564-1528).

Sincerely,

for RLD

Robert L. Duprey, Director
Hazardous Waste Management Division

Enclosure

cc: Thomas P. Looby, CDH
David Shelton, CDH
Lt. Col. Scott P. Isaacson
Chris Hahn, Shell Oil Company
R.D. Lundahl, Shell Oil Company
Thomas Bick, Department of Justice
David Anderson, Department of Justice
Preston Chiaro, EBASCO

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RESPONSE TO COMMENTS BY U.S. ENVIRONMENTAL
PROTECTION AGENCY, REGION VIII, ON GROUNDWATER
INTERCEPT SYSTEM NORTH OF BASIN F
INTERIM RESPONSE ACTION DRAFT ARARS

I. Potential Contaminant-Specific ARARs.

Comment 1: Contaminant-specific ARARs identified by the North Boundary System (NBS) interim action should be considered here, particularly since no other design or performance criteria are outlined.

Response: Contaminant-specific ARARs identified for the NBS were considered here. These potential ARARs were not considered applicable or relevant and appropriate for this IRA. The Basin F groundwater treatment system IRA would treat groundwater and reinject it within the boundaries of RMA. Within RMA, use of groundwater for consumption is prohibited. These use restrictions are extremely effective. The installation is fenced and patrolled by armed guards. Groundwater treated by this IRA would flow for some period of time, probably measured in years, towards either the Northwest or North Boundary System where it would be treated once again. Since water treated by the Basin F system is not subject to consumptive use prior to further treatment, the potential contaminant-specific ARARs considered for the NBS improvement were neither applicable nor relevant and appropriate to apply here. The Army is not aware of any other sites utilizing internal groundwater treatment systems and boundary treatment systems, amounting to sequential treatment prior to any possible exposure, to utilize as a design criteria. The Army is considering using the standards set by EPA OSWER Directive 9360.1-01, 10/06/87, as a design goal for the Basin F system. These standards would not be ARARs, but provide design criteria for technical personnel to attempt to attain.

Comment 2: Contaminant-specific ARARs may not be protective of human health and the environment. (Note-comment also submitted concerning NBS IRA).

Response: A more detailed discussion of this comment is provided in the NBS contaminant-specific ARARs response. The Army is aware that the risk assessment procedures in progress with EPA assistance may develop health-based criteria that are below ARAR levels. However, until that assessment is complete, only ARAR levels are available to be considered and it is not in the interest of the parties or the public to delay implementation of interim actions such as this until the risk assessment process is completed.

Comment 3: To the extent that groundwater standards which may be developed in the future by the State of Colorado are more stringent than federal standards they should be considered as potential ARARs.

Response: Standards adopted by the State in the future will be considered as potential ARARs.

Comment 4: Contaminant-specific drinking water standards should be considered as potential ARARs since the water will move off-site and appear in an aquifer which is continuous with drinking water aquifers.

Response: This comment was discussed in the response to comment 1. It is further noted that this water will not move off-site without further treatment by another groundwater treatment system, rendering the concern expressed premature in the context of this IRA.

II. Location-Specific ARARs.

Comment 1: EPA would appreciate the chance to review current evidence that this IRA will have no adverse impact on endangered species, migratory birds, or the protection of wildlife habitats.

Response: The Army is fortunate in that professional personnel of the U.S. Fish and Wildlife Service work almost continuously at the Arsenal and are available for expeditious consultation. A record of this consultation will be developed for other agencies or interested parties to review. The Fish and Wildlife Service have reviewed this document and "find no objection with this action that would seriously threaten wildlife of Federal concern." (See letter from the Fish and Wildlife Service at the beginning of Appendix D.)

Comment 2: EPA requests further clarification of the Army's statement concerning the release of air emissions during constructing and monitoring therefore.

Response: The need for monitoring and the design of the monitoring program for potential releases of air emissions will be determined after the actual construction technique has been selected.

Comment 3: EPA requests consideration of the National Emission Standards for Hazardous Air Pollutants (NESHAPS) at 40 CFR Part 61 as potential ARARs.

Response: The NESHAPS were considered as potential ARARs. They were not considered applicable since they apply to owners of stationary sources that emit the regulated pollutants. They were not considered relevant and appropriate since they were developed for manufacturing activities that are significantly dissimilar to the short-term construction activity involved in this IRA.

Comment 4: EPA requests further discussion of potential ARARs which may apply to excess contaminated material resulting from construction.

Response: As in other actions, the Army will follow the guidance of the EPA, Region VIII, memorandum of June 12, 1985, concerning screening and handling of potentially contaminated material. Excess material determined to be contaminated will be managed in accordance with the substantive requirements of 40 CFR Parts 260 through 264, as appropriate.

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June 1, 1988

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AIRBORNE EXPRESS

Re: Groundwater Intercept System North of Basin F Interim Response Action Draft Applicable or Relevant and Appropriate Requirements Document

Dear Dave:

In response to Wallace Quintrell's May 2, 1988, letter to Jeff Edson regarding the above-referenced matter, the Groundwater Intercept System North of Basin F is subject to the Colorado Hazardous Waste Management Act (CHWMA), the regulations promulgated thereunder, the CDH Modified Basin F Closure Plan, the Resource Conservation and Recovery Act and the regulations promulgated thereunder. Accordingly, any action taken by the Army with regard to Basin F must be taken in accordance with CHWMA, the CDH Modified Basin F Closure Plan, and all other pertinent state and federal laws and regulations. These laws and regulations are not mere ARARs. They are non-waivable requirements of the Solid Waste Disposal Act pursuant to CERCLA Section 120(i). Therefore, an ARARs determination is unnecessary.

Nonetheless, the ARARs document requires comment. By providing specific comment, the State does not intend to and is not waiving its claim that any remediation performed at or around Basin F is subject to CHWMA and the regulations promulgated thereunder.

As the State has previously informed the Army (see State comments on the proposed consent decree), any activity conducted at RMA must be conducted in compliance with all statutes and regulations. The Army agrees with the statement. See page 4 of this draft ARARs document which recognizes that, "[w]hile these provisions are not ARARs, they obviously must be complied with

for purposes of this IRA." Even though the ARARs package deals exclusively with the construction of the Basin F intercept system, the State disagrees with the statement that the Safe Drinking Water Act and the National Primary Drinking Water Regulations do not come into play. Therefore, where groundwater is extracted, treated and reinjected on-site or off-site, the above-referenced drinking water standards and the below listed groundwater standards must be met for organics and inorganics:

- Colorado Water Quality Control Act, 25-8-101, et seq., C.R.S.

  1. Basic Standards for Ground Water, 5 CCR 1002-8, Sections 3.11.0 et seq.

  2. Basic Standards and Methodologies, 5 CCR 1002-8, Section 3.1.0, et seq. (in particular Section 3.1.11).

Similarly, the intercept control system may need to comply with additional Colorado statutes and regulations. Therefore, the State requests that an RMA Committee meeting be scheduled to discuss the intercept system ARARs document.

Sincerely,

FOR THE ATTORNEY GENERAL

[signature] for

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RESPONSE TO COMMENTS BY THE STATE OF COLORADO
ON THE GROUNDWATER INTERCEPT SYSTEM NORTH OF BASIN F
INTERIM RESPONSE ACTION DRAFT APPLICABLE OR RELEVANT AND
APPROPRIATE REQUIREMENTS

Comment: Where groundwater is extracted, treated and reinjected on-site or off-site, the Safe Drinking Water Act, National Primary Drinking Water Regulations, Colorado Water Quality Control Act, Basic Standards for Ground Water 5 CCR 1002-8, Sections 3.11.00 et seq., and Basic Standards and Methodologies, 5 CCR 1002-8, Section 3.1.0, et seq. (particularly Section 3.1.11) groundwater standards for organics and inorganics must be met.

Response: The Army's analysis of the applicability and relevancy and appropriateness of standards established under the Safe Drinking Water Act is discussed in detail in the response to comments submitted by U.S. EPA, Region VIII. The Colorado Water Quality Control Act was reviewed and determined to contain no substantive standards. The Act recites legislative goals, establishes a water quality control commission, establishes a permit system and procedures therefore but does not establish any standard or criteria for the control of any pollutant. The Colorado Basic Standards and Methodologies were reviewed but not considered applicable nor relevant and appropriate since they are intended to apply to domestic water supplies and in circumstances where aquatic life must be considered. The groundwater treated by this interim action does not provide domestic water to any household and is subject to further treatment before leaving the boundaries of the Arsenal. No aquatic life is present in this groundwater to be protected contemplated by this regulation. The water being treated by the Basin F groundwater treatment system does not meet the definitions of Aquatic Life, which only apply to surface water, or Domestic Water Supply as established in the Regulation. The tables contained in the regulation are guidelines and "carry no presumptive validity or applicability," (5 CCR 1002-8, TABLES). The Basic Standards for Groundwater, 5 CCR 1002-8, Sections 3.11.0 et seq. were reviewed and determined to be neither applicable nor relevant and appropriate. These regulations are not automatically applicable to groundwater and they are not relevant and appropriate to apply to this interim action. Treated groundwater from the contemplated treatment system will not be used for agricultural or domestic purposes on the Arsenal and is subject to further treatment by the boundary groundwater treatment systems prior to leaving the Arsenal boundaries. Under the specific circumstances of this interim action, it is not appropriate to apply these groundwater standards.